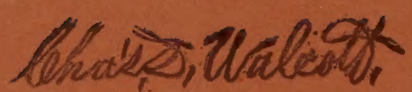

Fossil Estheria

THE

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A MONOGRAPH

OF THE

FOSSIL ESTHERIÆ.

BY

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PREFACE.

The materials of this Monograph have been accumulating for more than ten years; but the obscurity of some of the specimens, and the necessity of obtaining direct information from friends, both at home and abroad, acquainted with these fossils and the strata in which they are found, have caused considerable delay. Other interruptions, especially of late, have also thrown me off the study. Still the protracted time has brought many new facts to light regarding *Estheriæ*, both recent and fossil, as well as several new species and varieties.

I have been careful to give a full account of localities, and of sections in particular, that enquirers may seek for more specimens, and that they may be still more careful than heretofore in noting the exact contents and characters of the Estherian and associated strata. As fossil *Estheriæ* occur mostly in the passage-beds between the great Formations, and in the estuarine and freshwater equivalents of the marine portions of those Formations, the exact study of the Estherian beds cannot but prove of value in Geology, though the correlation of the beds may be somewhat difficult. The early appearance and long continuance of the Estherian type, and its wide distribution, are subjects of great interest to the Palæontologist.

I have a host of friends and kind helpers to thank for the assistance which they have rendered me, in various ways, always readily, and often at a considerable cost of time and

labour. Amongst my foreign friends I reckon some who gave early attention to the Triassic *Estheria minuta*, especially the late much lamented H. G. Bronn, the veteran F. von Alberti, and Naumann, as well as Geinitz, Beinert, Dunker, F. Sandberger, Oppel, Krantz, Hassencamp, Daubrée, Schimper, Engelhardt, E. d'Eichwald, Pander, G. von Helmersen, C. M. Wheatley of Pennsylvania, and W. B. Rogers of Boston, whose brother, Professor H. D. Rogers (Glasgow) has also eminently aided me. The late Mr. P. Duff, Dr. Mantell, and Prof. Quekett, Dr. W. Baird, Sir C. Lyell, Sir R. I. Murchison, the Rev. Messrs. Symonds, Brodie, Hislop, Austen, and Fisher, Dr. Oldham, Prof. Morris, Mr. Binney, Mr. G. Tate, Mr. Salter, Mr. Peach, Mr. J. Miller, Prof. W. C. Williamson, Messrs. S. P. and H. Woodward, Mr. D. Forbes, Mr. Rofe, Mr. Grossart, Dr. Rankine, Mr. Leckenby, Mr. Bean, Prof. Tennant, Mr. E. Hull, Mr. Etheridge, Mr. Kirshaw, Mr. C. Moore, Mr. Beckles, Dr. T. Wright, Mr. J. Plant, Mr. G. E. Roberts, Mr. C. E. Austin, and Mr. H. Seeley, must be enumerated as sources either of material or information for this Monograph; and my friend, Mr. G. West, must be especially thanked for the patient care bestowed on the drawings, and for the great skill with which he has helped me most materially in unravelling many obscure points of structure.

Some of the best and rarest of the specimens illustrated in this Monograph are in the British Museum, the Museum of the Geological Society, and that of the Geological Survey: to the officers of these Museums my thanks are especially due.

To render the history of *Estheria* as complete as circumstances permit, I have described, in an Appendix, those other fossil bivalved *Entomostraca* that are in direct association with the *Estheriæ*,—that is, occurring in the same strata. I hoped that they might throw additional light on the habitats of the ancient *Estheriæ*; the results, however, are not conclusive; but will probably be found useful.

CONTENTS.

APPENDIX.

ERRATA ET CORRIGENDA.

Page 3, line 24 from the top, *for* Northumberland *read* Berwickshire.

Page 4, lines 2 and 3, *for* age (probably Tertiary) in Siberia, &c., *read* age in Siberia (Tertiary ?) and South America (Mesozoic ?).

Page 5, line 10 from the top, for *Estheria* read *Estheriæ*.

Page 20, lines 8 and 27, *for* Colonel *read* General.

Page 37, line 11 from the top, *for* Salbach *read* Sulzbach.

Page 38, last line, and page 40, line 22, for *Cytheropsis* read *Beyrichia*.

Page 41, line 20 from the top, *for* localities *read* locality.

Page 45, line 11 from the top, after *Estheria insert* (very rarely).

Page 49, last line, *for* From *read* According to.

Page 52, lines 8, 10, and 11, *transpose* [3] from *Albertii* to Soultz-les-Bains; and [4] *from* remains *to Albertii*.

Page 65, line 14 from the top, *for* above *read* about.

Pages 67, 69, and 71, in the heading, *add* VAR. BRODIEANA *after* MINUTA.

Page 81, line 19, *after* Proportion *insert* 3 to 5 or.

Page 87, line 21, *for* marls *read* shales, *and for* shales *read* slates.

„ last line of the notes, *for* this *read* the.

Page 88, line 23, *insert* a comma after *Estheriæ*, and *dele* the comma *after* sandstone.

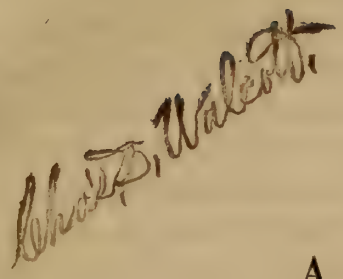
Page 89, line 21, *for* Dan River *read* Deep River. (The section of Egypt Pit ought to come in at page 90, after the table of the "Chatham Group.")

Page 91, line 15 from the top, *after* Deep River Series *insert* See Appendix for a notice of *E. ovata* from this series.

„ line 17, for *trigonalis* read *triangularis*.

„ line 29, for *angularis* read *triangularis*.

Page 95, in the section, *insert* 25 *between a* and 24.



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INTRODUCTION.

Geologists, looking at fossils as witnesses of the varied conditions of land and water in remote times, desire to inquire fully into the probable habits and relationships of every organic relic of the past. Fossil shells, forming the chief portion of the materials in the hands of the palæontologist, become especially the subject of such inquiries, and are made to yield evidence as to the relative age and the mode of formation of the several strata in which they occur. It is by comparing the extinct shells with those now living, and assuming for the fossil mollusc habits similar to those belonging to the most nearly allied of its existing congeners, that geologists for the most part form a judgment as to the character of many strata, whether they were marine or fluviatile in their origin, whether formed in shallow or in deep water. We are not surprised that the evidence thus obtained should often be weak and occasionally faulty, seeing that mere similarity in the form of shells has sometimes to be taken as evidence of generic relationship or of specific identity; whereas the soft parts of the mollusc, now lost, might have borne other evidence.[1] In nothing are naturalists so much deceived as by the manifold mimetic resemblances occurring throughout all kingdoms of nature. These are not wanting between

[1] A marked instance of palæontological uncertainty as to the relationships of certain bivalves occurs in the case of some of the "Rhætic" fossils, thus alluded to by Mr. Charles Moore, in the 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 502, when describing them under the generic name "Axinus, Sowerby:"—"Few shells have been subject to greater transposition, or have been placed under so many different

different groups of the molluscs themselves,[1] and they are very striking in the case of certain Bivalved Crustaceans (forming the subject of this monograph), closely resembling in general form some of the Molluscous Bivalves. A glance at the accompanying plates illustrating some fossil Bivalved Crustaceans reminds us of many well-known forms of Lamellibranchiata, such as *Posidonomya*, *Modiola*, *Myacites*, *Anodon*, *Unio*, *Cyclas*, *Pisidium*, *Kellia*, *Turtonia*, *Nucula*, and others; and indeed some of the species here figured have been referred by palæontologists to *Posidonomya* and other molluscs. It has, however, generally been felt that there was a difficulty in the exact determination of these little shells; still a rigorous examination of their form and structure was wanting, the pocket-lens only, and not the microscope, having been brought to bear on them.

Being subjected to the microscope, and drawn by means of the camera-lucida, many of these minute shells no longer appear with the outlines given to them by older plates and woodcuts; thus, *Estheria membranacea*, when perfectly portrayed, is no longer the triangular "Cyclas" or "Venus" of older figures, but has a semi-orbicular Posidonomya-like form. On the other hand, *E. minuta* has more of the Pisidium-shape than its old name "Posidonomya" would indicate. The microscope, moreover, exhibits the peculiar superficial ornament so characteristic of the Bivalved Crustacea, and wanting in the Mollusca; but of this ornamentation of the *Estheriæ* we had at hand the published illustrations and descriptions, by Dr. W. Baird, in the 'Zoological Society's Proceedings,' 1849, &c.;

genera, as those included in the group under notice. Von Credner, in 'Leonhard und Bronn's Jahrbuch,' 1860, p. 307, remarks that one of the Rhætic species has by Roemer been called *Venus liassica*, but without a figure; by Quenstedt, in 'Der Jura,' *Opis cloacinus;* that Escher notices it, but without naming it, from the Kössen beds; by Oppel and Suess it is called *Schizodus cloacinus;* and that it had previously been given by Bornemann, but without a figure, as *Tæniodon Ewaldi* of Dunker.

"In previous notices of the fossils from this zone, by Mr. Strickland, the Rev. P. B. Brodie, and also by Dr. Wright, reference is made to a shell called *Pullastra arenicola*, Strickl., which is said to occur very abundantly, but only in casts, and of which no figure has been given; there is no doubt it belongs to the group under consideration. They have also been included by other English authors under the genera of *Tellinites*, *Isocardia*, *Cucullæa*, *Donax*, *Sedgwickia*, and *Schizodus*. It is not clear wherein the following shells from Beer-Crowcombe differ from the *Axinus* of Sowerby; and his name, having priority, is therefore retained."

We must recollect, however, that we have in this case a set of dwarfed shells, probably of brackish-water habitat.

[1] In a memoir in the 'Philosophical Transactions' for 1835, Dr. J. E. Gray treats of "shells having every appearance of belonging to the same natural genus, but inhabited by animals of a very different character" (p. 301); and, as examples, he enumerates—

Pupa and Vertigo.	Cytherea and Artemis.
Vitrina and Nanina.	Cyclas and Pisidium.
Rissoa and Truncatella.	Paludina and Littorina.
Siphonaria and Ancylus.	Littorina and Phasianella.
Littorina and Assiminia.	Neritina and Nerita.
Mytilus and Dreissena.	Bullia and Terebra.
Anodon and Iridina.	Aporrhais and Rostellaria.

and by this author and other crustaceologists the animals of *Estheriæ* and its allies, the *Limnadia* and *Limnetis*, had been already fully made known. Another important result of the application of the microscope to these once obscure organic remains was the determination of the intimate structure of the shell as belonging to crustacean and not to molluscan organisms. Whilst the shell of *Posidonomya Becheri* of the Lower Carboniferous rocks is truly of the molluscan type,[1] that of the so-called *Posidonomya minuta* and its allies is crustacean.

One of the fossil *Estheriæ* (*E. tenella*, passing under the name of *Posidonomya*) was regarded by Agassiz, in 1845, and by Naumann, in 1848, as being related to *Cypris*; Dr. Volger, in 1846, suggested of another (*E. minuta*) that it might be a bivalved Crustacean; and another (*E. ovata*) was suggestively referred to the *Cypris* and its allies by Lyell and Morris in 1847.

In 1856 the Rev. W. S. Symonds, F.G.S., favoured me with some well-preserved specimens of the little Triassic *Estheria*[2] from Pendock, Worcestershire; and with the late Prof. J. Quekett's kind assistance I was enabled to see most distinctly the true crustacean character of the tissue of its valves under the microscope. This confirmed an opinion I had long held, and which had been previously advanced by Agassiz and Naumann,[3] by Volger[4] and by Lyell and Morris,[5] that some of the little fossils known as *Posidonomyæ* are not molluscs, but closely allied to the *Limnadia*, *Limnetis*, and *Estheria*, bivalved phyllopodous Crustaceans (*Entomostraca*) of the present day; and, indeed, as far as the carapace-valves are concerned, this and the other so-called *Posidonomyæ* referred to correspond to the *Estheriæ* of Rüppell and Baird[6] (*Isaura*, Joly; *Cyzicus*, Audouin).

Different species of these fossil *Estheriæ* occur in the Devonian rocks (Caithness, Orkney, Livonia, and Russia); Carboniferous (Scotland, Northumberland, Lancashire, Derbyshire, Belgium, France, Bavaria, and Silesia); Permian (Ireland, Saxony, and Russia); Triassic (England, France, and Germany); Rhætic (Somerset, Gloucestershire, Warwickshire, Worcestershire, and Elgin); Oolitic (Skye and Scarborough); Purbeck (Dorset); and Wealden (Sussex and Hanover). Others are met with in the coal-fields of Lower Mesozoic age, in North Carolina and Virginia, and along their north-western extension, forming

[1] Having the late Professor Quekett's authority in deciding the molluscan character of a shell of the Lower Carboniferous *Posidonomya* from Northumberland, which we examined together under the microscope, I cannot agree with Mr. J. W. Salter in thinking it probable that the great *Posidonomyæ* of the Carboniferous rocks are crustacean, as suggested in his paper in the 'Annals Nat. Hist.,' 3d ser., 1860, vol. v, p. 153.

[2] This is the little Triassic shell that has been termed *Posidonia*, and *Posidonomya, minuta; Posidonia minuta* (Alberti), Goldfuss; *Posidonomya minuta*, Bronn, Zieten, Strickland, and others. In Morris's 'Catalogue of British Fossils,' 2nd edit., 1854, it is included in the *Crustacea* (as *Estheria minuta*); but (apparently from inadvertence) it has not been expunged from the list of molluscs in that work.

[3] 'Bullet. Soc. Géol. France,' 2nd ser., vol. v, p. 301, and vol. vi, p. 90.

[4] 'Neues Jahrbuch f. Min.' 1846, p. 818.

[5] 'Quart. Journ. Geol. Soc.,' vol. iii, p. 275, and Lyell's 'Manual of Geology,' 5th edit., p. 332.

[6] 'Proc. Zool. Soc.,' part 17, 1849, p. 87.

the so-called "New Red Sandstone" of Pennsylvania;[1] and in the plant-bearing sandstones of India (Mangali, Panchét, and Kotah); and in beds of undetermined age (probably Tertiary) in Siberia and South America.

Although occurring so constantly in the different geological periods, from the Devonian to the Wealden,[2] and again in some Tertiary beds and in the recent fresh waters, yet it is in the Rhætic and Triassic deposits of Britain and the Continent, and the sandstones and bituminous shales of Pennsylvania, Virginia, and Carolina, and in the plant-bearing beds of India, that this little Bivalved Entomostracan appears to be pre-eminently abundant, so as to serve probably as a faithful index of a peculiar geological horizon.[3]

In like manner, among the still lower forms of life, the Nummulite is represented in the Carboniferous, Liassic, Oolitic, and Cretaceous rocks, and exists also at the present day; but it particularly distinguished one epoch (the Tertiary) by a surprising fecundity and a temporary profusion of individuals.

The occurrence of a fossil *Estheria* in the Upper Sandstone and Shale of the Scarborough district (*E. concentrica*, Bean,[4] sp.) is of considerable interest, as indicative of the association of this crustacean genus with the Jurassic flora in England, as it is with a Jurassic-like flora in India and North America.

In India a Triassic Labyrinthodont reptile (*Brachiops laticeps*[5]) is found in the same strata as yield the *Estheria* at Mangali, possibly contemporaneous, or nearly so, with those containing plants at Nagpur; near Panchét also, in north-eastern India, *Estheria* occurs in equivalent beds, with Dicynodont and Labyrinthodont remains; and in Pennsylvania reptilian remains[6] occur with the so-called "Posidonomya;" in North America, indeed, the evidence seems to point to a contemporaneity of the coal- and plant-beds of Carolina and Virginia, the shales and sandstones of Pennsylvania and New Jersey, the foot-marked sandstones of Connecticut, and the Upper Red Sandstone of Nova Scotia and Prince Edward's Island, which is also reptiliferous;[7] and it is evident that in the Virginian and Pennsylvanian shales the minute crustaceans under notice are important fossils. The fossil plants of India and of Virginia and Carolina having a Jurassic facies, like those of the Venetian Alps and Scarborough, it will be interesting, as further evidences turn up, to see how far we are to regard the Triassic or the Jurassic element as preponderating, or

[1] Continuous with the sandstones of New Jersey, and most probably with those of Connecticut also.

[2] I have no satisfactory evidence of the presence of the genus in question in the Cretaceous deposits.

[3] Prof. W. B. Rogers has already pointed out ('Boston Nat. Hist. Soc. Proc.' v, p. 15, &c.) the probable value of this little fossil in the comparison of the Mesozoic rocks of North Carolina and Virginia, and of these with the so-called Triassic beds of the United States.

[4] 'Mag. Nat. Hist.,' vol. ix, p. 376.

[5] 'Quart. Journ. Geol. Soc.,' vol. ix, pp. 37 and 371.

[6] Lea on *Clepsysaurus Pennsylvanicus*, 'Journ. Acad. N. Sc. Philad.,' n. s., vol. ii, p. 185; and on *Centemodon sulcatus*, 'Proc. Acad. N. Sc. Philad.,' n. s., vol. viii, p. 377.

[7] Leidy on *Bathygnathus borealis*, 'Journ. Acad. N. Sc. Philad.,' n. s., vol. ii, p. 327.

whether a passage-group of deposits ("Rhætic") are indicated by the evidence; or, lastly, whether these Plant-beds with Reptiles and Crustaceans indicate the terrestrial and lacustrine conditions only of the early Mesozoic period.

The Jurassic-like flora of Australia[1] and that of southern Africa have been hitherto collected without affording any clear traces of the *Estheria*. The latter country, however, has its probably Triassic reptiles, the *Dicynodon* and its many associates, imbedded with this flora;[2] so that the peculiar association above indicated for India and North America obtains there also.

In pointing out these facts of the geological and geographical distribution of the fossil *Estheria*, I merely touch upon the salient points of an interesting subject of research, for the elucidation of which careful inquiry at home and abroad is still requisite.

The known species of living *Estheria* are—

Estheria gigas, *Hermann*, sp. Baird, Proc. Zool. Soc., 1849, p. 87 (=*Cyzicus Bravaisii*, Audouin, Annal. Soc. Entom. vi, Bullet., p. ix, 1837; *Isaura cycladoides*, Joly, Annal. Science Nat., 2 sér., 1842, xvii, p. 293, pl. 7, 8, and 9 a (figs. 1—45); *Estheria cycladoides*, Lucas, Explor. Scientif. Algerie, Crustacés, 81, 1845.	Freshwater pools, Strasburg (*Hermann*); brackish water marsh, Arzeu, near Oran, Africa (*Bravais*); ditch filled with rain-water (in June), Toulouse (*Joly*); Tunis (*Frazer*); Algeria (*Lucas*).
— Dahalacensis, *Straus-Durckheim*. Mus. Senckenb., ii, p. 119, pl. 7, figs. 1—16; Baird, Proc. Zool. Soc., 1849, p. 89, Annulos. pl. 17, figs. 2—4.	Freshwater marshes of the Island of Dahalac, on the coast of Abyssinia, in December (*Rüppell*); and in stagnant water, on the banks of the Tigris, near Bagdad (*W. K. Loftus*).
— Melitensis, *Baird*. Proc. Zool. Soc., 1849, p. 88, Annulos. pl. 11, fig. 2.	Rain-water pool, Malta (*Hennah*); Sicily (*Cuming*).
— polita, *Baird*. Ib., fig. 3.	India (interior, N. E.), *Boys*.
— Brasiliensis, *Baird*. Ib., p. 89, pl. 11, fig. 4.	Brazil (*Sowerby*).
— donaciformis, *Baird*. Ib., fig. 5.	Abeyd (White Nile), Kordofan (*Parreyss*).
— Boysii, *Baird*. Ib., fig. 6.	India (interior, N. E.), *Boys*.
— similis, *Baird*. Ib., fig. 7.	India (interior, N. E.), *Boys*.
— tetracera, *Krynicki*, sp. Bullet. Soc. Imp. Nat. Moscou, ii, 1830, p. 176, pl. 7, fig. 1; Baird, Proc. Zool. Soc., 1849, p. 90.	Freshwater marsh (in May), near Charkow, Russia, and at and near Moscow (*Krynicki, Fischer, and de Laveau*, 1817—29).
— Dallasii, *Baird*. Proc. Zool. Soc., 1852, p. 30, Annulos. pl. 23, fig. 5.	Brazil (?) *Dallas*.

[1] See M'Coy's paper, 'Ann. and Mag. Nat. Hist.,' vol. xx, p. 145, &c.; and the Rev. W. B. Clarke's, 'Quart. Journ. Geol. Soc., vol. xvii, p. 354. Labyrinthodont reptiles have not been wanting in Australia; see Professor Huxley's paper on the *Bothriceps Australis*, 'Quart. Journ. Geol. Soc.,' vol xv, p. 647.

[2] Glossopteris, &c.; 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 329. Dicynodont remains have also been discovered lately in connection with the coal-bearing strata of Bengal (ibid., p. 362, and Mem. Geol. Surv. India, vol. iii, part 1.)

Estheria Hislopi, *Baird.* Proc. Zool. Soc., 1859, p. 232, pl. 63, fig. 1.	Freshwater stream, near Nagpur, central India (*Hislop*).
— compressa, *Baird.* Proc. Zool. Soc., 1860, p. 188, pl. 71, fig. 6.	Freshwater pools, Nagpur (*Hislop*).
— Birchii, *Baird.* Ibid., p. 392, pl. 72, fig. 1.	Pools of freshwater, on the banks of the Wamoi River, Australia (*Birch*).
— Gihoni, *Baird.* Ann. Mag. Nat. Hist., 3rd ser., vol. iv, 1859, p. 281, pl. 5, fig. 1.	Freshwater pool of Gihon, Jerusalem. *E. Gihoni* was reared in England, by Mr. H. Denny and Dr. Baird, from the dry mud brought from the Pool of Gihon.
— Hierosolymitana, *Fischer.* Abhandl. k. bayer. Akad. Wiss. München., viii, 1860, p. 649, pl. 20, figs. 7, 8.	Rain-water pools on limestone, near Jerusalem, dry for ten or eleven months in the year (*J. R. Roth*).
— Australis, *Lovén.* Öfvers. af K. Vet. Ak. Förh., Årg. 3, 1846 (Stockholm, 1847), p. 57.	Freshwater marshes, Natal (*J. Wahlberg*).
— Dunkeri, *Baird,* MS.	Zimapan, in the neighbourhood of Mexico, where it lives with *Planorbis nitens,* Ph., *Limnæus subulatus,* De Kr., *Physæ,* and other molluscs, in stagnant waters (*Dunker,* Nordd. Wealdenbild., 1846, p. 61).
— Jonesi, *Baird,* MS.	Brackish water, Cuba (through *Dr. Dunker*).
— Loftusi, *Baird,* MS.	Stagnant water, on the banks of the Tigris, near Bagdad (*W. K. Loftus*).
— Caldwelli, *Baird,* MS.	Lake Winnipeg (*W. Caldwell*).
— Rubidgei, *Baird,* MS.	From the bed of a dried-up "vley" near Port Elizabeth, South Africa (*R. N. Rubidge*).
— Macgillivrayi, *Baird,* MS.	Brackish lake at Green Point, Cape of Good Hope (*J. McGillivray*).

The closely allied genera *Limnadia* and *Limnetis* are known by the following species:

Limnadia Hermanni, *Ad. Brogn.* Baird, Proceed. Zool. Soc., 1849, p. 86, Annulos. pl. 11, fig. 1.	Freshwater pool, Fontainebleau (*Brongniart*).
— Mauritiana, *F. E. Guérin.* Magas. de Zool., Sept. Année, Class VII. p. 1—7, pl. 22 (21 in the text) figs. 1—11, 1837; Baird, Proc. Zool. Soc., 1849, p. 87.	Mauritius (*Julien Desjardins*).
— Antillarum, *Baird.* Proc. Zool. Soc., 1852, p. 30, Annulos. pl. 23, fig. 1.	San Domingo (*Sallé*).
— coriacea, *Haldemann.* Proc. Philad. Acad., 1842, vol. i, p. 184; and 1854, vol. vii, p. 34.	"In ditches along the Susquehanna, in quiet water;" in "roadside ditches" (*S. S. Haldemann*). In fresh water, Cincinnati (*T. Kite*).
Limnadella Kitei, *Girard.* Ibid., 1854, vol. vii, p. 3.	
Limnetis brachyurus, *Müller.* Entomost., p. 69, t. 8, figs. 1—12.	Freshwater marshes, Denmark (*Müller*).

Limnetis Wahlbergii, *Lovén.* Öfvers. k. Vet. Akad. Förh., Årg. 3, No. 2, p. 57, 1847.		Freshwater marshes, Natal (*J. Wahlberg*).
— Gouldii, *Baird.*		Fresh water, at St. Ann's, twenty miles from Montreal (*C. Gould*).[1]

The recent *Estheriæ* are found in fresh water, rarely in brackish water. Guided by this fact, and taking for granted that our fossils were true *Estheriæ*, and that *Estheriæ* always have had freshwater habitats, we should suppose that the deposits in which these fossils are found, free from any appearance of having been drifted, must have been formed in rivers, lakes, or lagoons. Applying, however, the same rules in judging of the nature of the fossil molluscs and other organic remains that occasionally accompany some of these *Estheriæ*, we must regard the *Lingula* of the Old Red (of Livonia), the *Spirorbis*, the *Aviculæ*, the *Anthracosiæ*, and *Anthracomyæ*[2] of the Carboniferous shales, and the *Lingula* and *Pleurophorus* of the Trias, as truly marine shells. Many, however, of our fossil *Estheriæ* occur in strata destitute of any such evidence of marine conditions; and possibly the occasional mixture of the marine and freshwater organisms may have been the result of driftage (the free-swimming *Estheriæ* being readily swept away by a flood), or of very rapid changes of condition, such as might be brought about by the alternate occupation of a lagoon by sea- and river-water.[3] Seeing, too, that the recent *Estheriæ* appear, as it were, suddenly (like the *Apus*) in pools and ditches of rain-water, and are quickly developed in tanks and ponds dry for even ten or eleven months in the year, it is not unlikely that pools of fresh water, temporarily formed on a flat seashore, may have been inhabited by *Estheriæ*, destined to be quickly buried in the first wind-drift of sand, or at the return of high tides. As an inhabitant of brackish water, the *Estheriæ* would be still more likely to have been occasionally accompanied by marine shells: nor can we say that the fossil associates quoted above were not inhabitants of brackish water, or of salt lakes; for experience is the only guide to the naturalist in determining whether the members of many of the molluscan groups affect marine, brackish, or freshwater habitats.

Perhaps some might like to think that at first marine conditions alone suited aquicolous animals, and that some have subsequently taken to brackish and freshwater habitats; and this may have been the case with *Estheria:* but, except for the "progressive" aspect of the argument, the converse might just as well hold good for the *Lingula*,[4] *Spirorbis*, *Avicula*, *Anthracosia*, *Anthracomya*, and *Pleurophorus*, mentioned as being found in the older rocks in company with *Estheria*.

Of the living molluscan genera that are known to have fluvicolous as well as marine

[1] Dr. Baird has kindly assisted me in drawing up this table of the recent *Estheriæ* and their allies.

[2] According to Mr. Salter, 'Mem. Geol. Survey, 1861, Iron-ores of South Wales,' &c.

[3] See Sir C. Lyell's observations on the value of *Spirorbis* (in the fossil state), and barnacles (recent) in certain cases, as evidences of the occasional inroad of salt water into swamps, killing the marsh-plants and leaving behind such shells as the above, as well as *Modiolæ*, &c. ('Notices of the Royal Institution of Great Britain,' vol. i, p. 285.)

[4] See further on, for remarks on the *Lingula tenuissima* of the Trias.

species, the following are the most prominent:—*Rissoa* (*Assiminia*), *Cerithium* (*Potamides*), *Arca* (*Scaphula*), *Solecurtus* (*Novaculina*), *Mytilus* (*Dreissena*), and *Cardium*,[1] but how the extinct genera were circumstanced in this respect, and whether the old species of extant genera had similar habitats to those of their existing congeners, can only be partially surmized, chiefly from the evidence of the best known of their associates.

There are some existing genera the species of which appear to be essentially fluviatile, but live also in company with true marine shells in the mouths of rivers; these are *Cyrena* and *Ampullaria*. Such, too, may have been the habit of the old *Estheriæ;* at all events, there is no necessity for supposing them to have been marine; but where they occur by themselves, or in the company only of fishes[2] and plants,[3] they may be regarded as having lived and died in fresh (or possibly brackish) water; where they are mixed with shells of presumed marine character, they indicate probably that fresh water was in close proximity to the place of deposit, if it had not been replaced by the sea by possibly frequent alternations.

We must not forget, however, that, judging by analogy, the Entomostracous Crustaceans under notice may have been capable of living, at least for considerable periods, in even salt water, for some of the common *Cyprides*, such as are abundant in freshwater streams, are not uncommon in ditches of brackish and even highly saline water in the low grounds near the sea.

[1] In Dr. J. E. Gray's "Memoir on Testaceous Mulluscs," in the 'Philos. Transact.' for 1835, he treats of "Species of Testaceous Mollusca living in very different situations from the majority of the known species of the genus to which they belong, or having the faculty of maintaining their existence in several different situations;" and he illustrates the case (1st) of species of the same genus being found in more than one situation, as on land, and in fresh and in salt water, by *Auricula* (including *Conovulus* and *Chilina*); (2nd) of one or more species of a genus most of whose species inhabit fresh water being found in salt or brackish water, by *Limnæa*, *Neritina*, *Melania*, and *Melanopsis;* (3rd) of one or more species of a genus whose species usually inhabit the sea being found in fresh or brackish water, by—

Aplysia,	*Mya*,
Cerithium,	*Corbula*,
Bulla,	*Ostrea* (?)
Littorina (*Lithoglyphus*),	*Cucullæa* (*Scapula*),
Solen (*Novaculina*),	*Neritina* (*Theodoxus*),
Tellina,	*Ampullaria* (?), and
Avicula,	*Cardium*.

M. Beudant found by experiment (1803—1816), that many freshwater molluscs can be made by degrees to live in water gradually salted to the ordinary saltness of the sea; and that many marine molluscs can also, by gradually diminishing the saltness of the water, be accustomed to live in fresh water. See 'Comptes Rendus,' May 13th, 1816; 'Annales des Mines,' 1816, vol. i, p. 397, and De la Beche's 'Selection of Geological Memoirs,' 1824, p. 36.

[2] With some exceptions, it is impossible to say of any fossil fish that it did, or that it did not, belong exclusively to the sea, even when it is occasionally associated with marine fossils, as some of the Old Red fishes are in Russia. Many genera of fishes are as capricious, as to the habitats of their species, as the above-quoted molluscs are. Nor must we forget that the stony-scaled and plated fishes of Palæozoic times are now best represented by the Bichirs and the Sheat-fishes of existing rivers (Huxley; 'Mem. Geol. Surv.,' 1861).

[3] The association of remains of land-plants with the *Estheriæ* is of frequent occurrence.

The following Table shows the distribution of the fossil *Estheriæ* and *Leaiæ*[1] described in this Monograph, and the organic remains found in association with them :—

Genus and Species.	Locality.	Geological Stage.	Associated Organic Remains.
Esth. membranacea, *Pacht*, sp.	Livonia	Old Red	Lingula. Fishes.
„ „	Caithness	Old Red	Fishes.
E. striata, *Münster*, sp.	Bavaria	Lower Carboniferous	
„ „	Belgium	Lower Carboniferous	
„ „ var. Tateana	Berwickshire	Lower Carboniferous	Spirorbis. Fish. Plants. Cypridæ.
„ „ „ Beinertiana	Silesia	Lower Coal-measures	
„ „ „ „	Lancashire	Lower Coal-measures	Spirorbis. Cypridæ.
„ „ „ „	Lanarkshire	Lower Coal-measures	
„ „ „ Binneyana	Derbyshire	Lower Coal-measures	
„ „ „ Beinertiana	Lancashire	Middle Coal-measures	Fishes.
Leaia Leidyi, *Lea*, sp.	Pennsylvania	Lower Carboniferous	Plants.
„ „ var. Salteriana	Fifeshire	Lower Carboniferous	
„ „ „ Williamsoniana	Lancashire	Upper Coal-measures	Anthracosia.* Plants.*
Estheria tenella, *Jordan*, sp.	France (Autun)	Upper Coal-measures	Fishes * and Plants.*
„ „	Schwarzwald	Upper Coal-measures	Crustaceans* (*Gampsonyx*).
„ „	Lancashire	Upper Coal-measures	Beyrichia.
„ „	Lanarkshire	Upper Coal-measures	Spirorbis. Anthracosia. Avicula.
„ „	Saxony	Lower Permian	Fishes and Plants.
E. exigua, *Eichwald*, sp.	Russia	Permian	Beyrichia. Plants.*
E. Portlockii, sp. n.	Ireland	Permian	Fishes.*
E. minuta, *Alberti*, sp.	France	Bunter	Limulites.* Apus. Plants *
„ „	Hanover	Bunter	
„ „	Germany	Lettenkohle	Lingula. Pleurophorus. Lignite.
„ „	Hanover	Keuper	
„ „	Worcestershire	Keuper	Fishes* and Plants.*
„ „	Warwickshire	Keuper	Fishes.*
„ „	Somersetshire	Keuper	
„ „ var. Brodieana	Gloucestershire	Rhætic	Plants.
„ „ „ „	Somersetshire	Rhætic	Cardium (?). Plants. Insects.
„ „ „ „	Morayshire	Rhætic	Cypridæ. Reptiles.* Fishes.* Plants.*
E. Mangaliensis, sp. n.	India	Triassic or Rhætic	Reptiles.* Fishes.* Plants.
E. Kotahensis, sp. n.	India	Rhætic or Jurassic	Cypridæ. Fishes.* Plants. Insects.
E. ovata, *Lea*, sp.	North America	Triassic or Rhætic	Cypridæ. Fishes.* Plants.* Reptiles.
E. Murchisoniæ, sp. n.	Skye	Oolite	
E. concentrica, *Bean*, sp.	Yorkshire	Oolite	Plants (Ferns and Cycads).
E. elliptica, *Dunker*	Germany	Wealden	Cyrena. Cypridæ. Plants.*
„ „ var. subquadrata	Sussex	Wealden	Cyrena. Cypridæ. Plants.*
E. Forbesii, sp. n.	South America	Mesozoic?	Ferns or Cycads.
E. Middendorfii, sp. n.	Siberia	Tertiary?	Fishes (*Aspius*). *Paludina* (?). Plants. Insects.

Marked thus * not in the same seam, but in closely associated beds.

[1] *Leaia* is a problematical ally of *Estheria*. See the Appendix.

Some remarks on that subclass of the Crustacea known as Entomostraca have been made in my former Monographs on the Cretaceous and Tertiary *Ostracoda* (1849 and 1856); and, to show the place of Estheria in the Crustacean group, Mr. J. D. Dana's classification[1] is here produced.

CLASS.—CRUSTACEA.

Subclass I. Decapoda. II. Tetradecapoda. III. Entomostraca.

Subclass.—Entomostraca.
- *Ordo* I. Gnathostomata.
  - *Legion* I. Lophyropoda.
    - *Tribus* I. Cyclopoidea.
      - *Fam.* I. Calamidæ. II. Cyclopoidæ. III. Coryccœidæ.
    - *Tribus* II. Daphnioidea.
      - *Fam.* I. Penilidæ. II. Daphnidæ. III. Polyphemidæ.
    - *Tribus* III. Cyproidea.
      - *Fam.* I. Cypridæ.
        - *Subfam.* I. Cyprinæ (*Cypris, Candona*). II. Cytherinæ. (*Cythere*).
      - *Fam.* II. Halocypridæ.
        - *Subfam.* I. Cypridininæ. II. Halocyprinæ.
  - *Legion* II. Phyllopoda.
    - *Tribus* I. Artemioidea.
      - *Fam.* I. Artemiadæ. II. Nebaliadæ.
    - *Tribus* II. Apodoidea.
      - *Fam.* Apodidæ. (*Apus*).
    - *Tribus* III. Limnadioidea.
      - *Fam.* Limnadidæ.[2]
        - *Genus* 1. Limnadia, *Ad. Brongniart.*
        - 2. Cyzicus, *Audouin.* [*Estheria,* Rüppell.]
        - 3. Limnetis, *Lovén* (*Hedessa,* Lievin).
- *Ordo* II. Cormostomata.
  - *Subordo* I. Pœcilopoda. II. Pycnogonoidea (vel Arachnopoda).

Limnadia has the following diagnosis :—" Caput vix rostriforme, dorso tuberculum pyriforme gerente. Pedes toti foliacei. Abdomen extremitate appendicibus acuminatis quatuor armatum."

Cyzicus[3] [*Estheria,* Rüppell and Straus-Durckheim]. " Caput instar rostri productum,

[1] 'Report on Crustacea of the United States' Exploring Expedition,' 1853, pp. 1277, &c.

[2] *Apusiens* (in part) of Milne-Edwards, 'Hist. Nat. Crust., iii, p. 513.

[3] Audouin, 'Ann. de la Soc. Entom.,' vol. vi, 'Bullet.,' Feb., 1837, p. ix; *Estheria,* Rüppell and Straus-Durckheim, 'Mus. Senckenberg.' ii, 119, 1837; *Isaura,* Joly, 'Ann. Sc. Nat.,' 2 ser. xvii, p. 293, 1842.

Dr. Baird has the following observations on the generic name of this animal: " This genus was indi-

dorso non tuberculifero. Pedum paria numero fermé 21, foliaceorum. Abdomen ferè ac in Limnadiâ."

Limnetis. "Antennæ internæ 2-articulatæ. Cauda brevis, truncata, appendicibus facie inferiore destituta. Pedum paria 12."

The above-quoted diagnoses relate to the bodies and limbs of the three genera. In their carapaces they differ to some extent; *Limnetis* and *Limnadia* having a less perfect hingement and little or no umbo, and being generally destitute of concentric ridges; whilst in *Estheria* the carapace-valves have a definite hinge-line, well-marked umbos, and usually numerous distinct concentric ridges (boundary-lines of the periodic stages of growth of the carapace-valves). A reticulate sculpture ornaments the carapaces of the three genera; but in *Estheria* this ornamentation is stronger, and often modified by short vertical and inosculating bars.

The valves of *Estheria* are inequilateral, usually subtriangular or subovate; the umbo being almost always near the anterior end, and the edge of the valve and the parallel concentric ridges having a bolder curve posteriorly than in front. Occasionally, however, the umbo is almost central and the two ends of the valve nearly equal; the ventral edge of the valve and the concentric ridges having a nearly semicircular curvature. There are, however, numerous gradations of form between these extremes; so that I cannot see any grounds for a generic distinction being made between the subtriangular and the suborbicular forms on account of the relative position of the umbo.

In three instances I find shortened or subquadrate, or rather suborbicular, forms of carapaces accompanying others of subovate outline (*E. striata*, *E. Mangaliensis*, and *E. elliptica*). This difference of shape may be sexual, or due to conditions of growth.

cated by Audouin and Straus-Durckheim in the same year; the former proposing, for the species brought by M. Bravais from Oran, the name of *Cyzicus;* and the latter, for that brought by Dr. Rüppell from Abyssinia, the generic name *Estheria.* From the simultaneous publication of these two generic names, it is difficult to decide which should stand; and M. Joly, apparently feeling the difficulty, has proposed a third name, taking as the type the species found by him at Toulouse, and calling it *Isaura.* As M. Audouin merely indicates the genus, without giving a description of either genus or species, whilst M. Straus details at full length both generic and specific characters, and figures the typical species, I propose adopting his name, and retaining the generic name *Estheria*, a name originally proposed by Dr. Rüppell himself."

I coincide with Dr. Baird's opinion as to the propriety of using the term *Estheria;* and the more readily, because, as I have elsewhere stated, I believe that in the case of appellations invented for *groups* of animals, plants, or minerals, whether they be names of genera, families, orders, or classes, it is not always priority that should determine the general use of such terms, but either their adaptability, the preciseness of their definition, or other advantageous characteristics, as the case may be. With "specific" names, however, the case is different; the published name of a species is (or ought to be) not only the established appellation of a distinct form in nature, but also the registered evidence of the successful labour and acumen of its discoverer and describer.

Dr. S. Fischer assigns a shorter carapace to the female of his *E. Hierosolymitana*[1] than the one belonging to the male. The squarer carapaces above referred to are rare among the subovate individuals: some of the latter certainly bear what appear to be ova.

Of *Isaura cycladoides* (*Estheria gigas*) M. Joly has remarked that in its young state it undergoes certain successive changes of form, more or less analogous to the persistent conditions of "*Artemia, Branchipus, Apus, Daphnia, Lynceus, Cypris, Limnadia,* and *Cyzicus;*" one of these stages being marked by the presence of a horizontal Apus-like carapace, and others being accompanied by varied outlines of the carapace-valves. These observations should make us very careful in the examination of the different forms of carapaces, especially those found associated in the same set of strata, and prepare us for the possible specific identity of dissimilar carapaces.

Recent *Estheriæ* have sometimes so thin a carapace that the valves curl up when dry, like horn-shavings or flakes of quill. In other cases, however, the valves are stout enough to retain their convex oviform or Cycladiform shape when dry. Fossil *Estheriæ* also have varied in this respect. We sometimes find in them more variety of ornamentation on one and the same valve than has been observed in single recent specimens. Possibly, however, a closer examination of some of the recent valves might show similar series of modified sculpture on individual specimens.

About twenty species of *Estheria* are known to occur in the recent state, and six or seven of the two allied genera *Limnadia* and *Limnetis*. (See page 5.) These are distinguished respectively either by differences in the form and ornament of the carapace, or by more or less important modifications of the limbs or other organs. Our characterisation of the fossil *Estheriæ* must necessarily be independent of the structural differences in the body itself; and it is therefore possible that the limited number of species indicated as fossil, and distributed by one and two through the several great accepted geological formations, might be somewhat enlarged if we set a high value on every recognisable difference in the outline and ornamentation of the valves. I have been careful, on the contrary, to restrict myself as far as possible in setting much value on slight modifications in the fossil *Estheriæ*.

When the umbo of the carapace-valve is near the anterior end, as is most frequently the case, we have a resemblance to some of the subtriangular and subovate Bivalve Molluscs, such as *Pisidium, Tellina,* &c.; when the umbo is more nearly central, there is sometimes a resemblance to *Avicula* or *Posidonomya;* and this likeness may be strengthened by the valves of the little *Estheria* being often wrinkled concentrically, the sharp ridges and neat interspaces being replaced by numerous convex ridges, and nearly all the original structure lost. Still a trace of the peculiar reticulate ornamentation is usually left; and the superinduced wrinkles are not so evenly convex as is usual in the *Aviculidæ*, nor so uniformly marked with parallel concentric striæ as is frequently the case with those shells (see Pl. I, figs. 31, 32, *Inoceramus Suessii,* Oppel). The valves are rarely so

[1] 'Abhandl. Akad. Wiss. München,' viii, p. 649, pl. 20, fig. 8.

quadrate as in the *Posidonomya* and *Inoceramus;* and neither the wrinkles nor the ridges (whichever may mark the valves of the *Estheria*) are bent off away from the umbo to follow the outline of the produced ears of the shell present in most of the *Aviculida*, but absent in *Estheriæ*. Nor is there any trace of furrows or teeth on the hinge in *Estheria*.

A general crumpling of the shell of a very thin *Avicula* or *Posidonomya* irregularly corrugates the whole surface, concentric wrinkles and all; but in *Estheriæ* the true ridges are seldom thus interfered with, but rather yield to the transverse pressure by taking on an obliquity of direction, leaving the sculptured interspaces to show the crumpling effect of pressure. Rarely converted into calcareous matter, the Estherian carapaces usually present a delicate, brownish, horn-like tissue, generally with some degree of transparency and polish, contrasting with the dull perfectly calcified shells of the *Aviculidæ*, or their bold wide-ridged impressions, black and filmy, or delicately nacreous. In carbonaceous deposits the *Estheriæ* often leave only black films or merely impressions. In one case a white siliceous (?) substance is found to replace the valves in a brown-coal. Sometimes a ferruginous film has replaced the carapace-valves, especially in sandstone.

As the *Estheria minuta* has been referred to *Posidonomya* so generally and for so long a time, it is highly probable that other little fossils of the same class still pass as *Aviculidæ* in palæontographical works and collections. That attention might be turned to these, I would point out some figured specimens which appear worthy of special microscopical examination. The small shells figured by Pusch ('Polen's Palæontolog.,'pl. 5, fig. 14) as the young of *Catillus Brongniarti* have a strong resemblance to *Estheria*, and are the more worthy of examination as they are said to come from the clay-beds above the Jurassic limestone. Figs. 11 and 12 of pl. 37 of Reuss's 'Kreideform. Böhm.' are not so promising; they may really belong to *Inoceramus Crispii* and *I. planus*, to which they are referred. Some of the fossils figured in pl. 17 of Lynch's 'Report on the Geology of the Dead Sea' might possibly be worth re-examination; also the Australian fossil figured in 'Annals Nat. Hist.' vol. xx, pl. 13, fig. 3. The *Posidonomya Wengensis*, Wissman, and *Avicula globulus*, Wissm. 'Münster's Beiträge,' iv, p. 23, pl. 16, figs. 12 and 13, from the St. Cassian beds of the Tyrol, should certainly be looked at by a crustaceologist. *Cardinia nana*, de Koninck, 'Anim. foss. Terr. Carb. Belg.' p. 71, pl. 1, fig. 6, is another little shell to be examined. In the 'Geognostische Skizze der Umgegend von Ilmenau am Thüringen Walde' (Zeitschr. deutsch. geol. Gesell. xii, 1860), Herr Karl von Fritsch remarks (p. 144), "Near Goldlauter, not far from Ilmenau, some beds are nearly full of *C. nana*. These flattened shells remind one of the Triassic *Posidonomya minuta*, Bronn. Perhaps it is the same shell as von Gutbier mentions in his 'Versteinerung. des Rothliegendes in Sachsen,' p. 7."

1. Estheria membranacea, *Pacht*, sp. Pl. I, figs. 1—7.

Posidonomya, *d'Eichwald.* Geology of Russia, (published in the Russian language), 1846, p. 399.

Asmusia membranacea, *Pacht.* Der Devonische Kalk in Livland, 1849, p. 44.

Posidonomya membranacea, *Pacht.* Ueber Dimerocrinites oligoptilus, 1852, p. 26; and Der Devon. Kalk. Livland, 2nd edit., 1859, p. 44, fig. 7.

— rugosa, *Kutorga.* Geognostische Karte des Gouvernements von Petersburg, 1852.

Estheria, *Rupert Jones.* Quart. Journ. Geol. Soc., 1855, vol. xii, p. 376.

? Posidonia rugosa (*Kutorga*). *Von Helmersen.* Geognostisch. Untersuch. mittl. Gouv. Russlands, 1858, p. 73.

Estheria Murchisoniana, *Rupert Jones.* Quart. Journ. Geol. Soc., 1859, vol. xv, p. 404, woodcuts, fig. 14, *c*, *d* (p. 408).

Asmusia membranacea (*Pacht.*), *Pander.* Monographie ueber die Saurodipterinen, &c., 1860, p. iv.

Height of valve, about $\frac{1}{8}$ inch
Length, nearly ..... $\frac{1}{8}$ „ } Proportion 9 to 11, or 1 : 1 +

This species occurs both in Scotland (Caithness) and in Russia (Livonia and elsewhere).

I shall describe the Scottish specimens first:—

Valves subquadrate, occasionally somewhat oblong in form, the majority being about 1-6th inch long and 1-8th inch high, whilst some are as high as long. Pressure, however, has interfered with the contours and proportions of many of these valves. The hinge-line is straight; the generality of the valves have the anterior and posterior edges forming sharp angles with the dorsal line and passing vertically with a slightly convex outline to the boldly rounded ventral border. In this case the umbo is distinct; almost, but not quite, in the middle of the dorsal line; and bordered by a triangular depressed, but not produced, ear on either side; the valve resembling somewhat that of a miniature *Posidonomya,* or upper valve of an *Aviculo-pecten.*

The surface is wrinkled, by about 18 to 20 concentric, rounded, closely set wrinkles, uniform with the outline of the ventral border and extremities of the valve. The wrinkles are coarsest near the umbo, their starting point, and they become finer as they approach the edges of the valve.

Under the microscope, between the broad wrinkles are seen, here and there, thin sharp ridges lying in the narrow furrows; and the patches of the outer surface, here and there retained, are seen to be of a dark-brown opaque substance, exhibiting on and between the

wrinkles a finely granular appearance, which is probably due to the modification of an originally minute reticulate ornament, by the pressure of the sand-granules of the matrix (fig. 5). Some layers of the valve, when exposed by flaking, are quite smooth, amber-coloured, and semi-transparent. The differences between the conditions here described and those observed in the better preserved specimens from Livonia will be pointed out when the latter specimens come to be described presently.

As it is possible that the difference in shape between the many subquadrate and the few oblong valves may be due to pressure, to a condition of growth, or perhaps to difference of sex, it would be too hazardous even to distinguish them by name as varietal forms.[1] Indeed, circumstances have so modified the great majority of the valves in the slabs of stone, on the bedding-planes of which they occur, that the whole outline of a valve can very rarely be definitely traced even among a hundred individuals; for the edges either overlap, are squeezed out of proportion, are broken away, or, lastly, remain buried a little way in the matrix.

The carapace-valves of this small bivalve Crustacean occur plentifully on some of the surface-planes of the Caithness Flagstones, near Wick, and also in the Orkney and Shetland Isles, and have been noticed by Hugh Miller and others.[2] Their close resemblance to the shells of small bivalve molluscs formerly led to their being taken for the shells of *Astarte*, *Venus*, *Cyclas*, &c.; but their supposed relation to molluscs having been doubted,[3] some specimens from near Thurso, collected by Mr. Peach, were given to me by Mr. Woodward, in 1855; and a far larger number, and better preserved, from Kirkwall and Murkle Bay (collected by Mr. Dick), were confided to me for examination by Sir R. Murchison in 1858.

In their substance, consistence, configuration, and size, these little valves offer direct analogies to the bivalved carapaces of certain recent Phyllopodous Crustaceans (*Estheriæ*) inhabiting the rivers and lagoons of hot countries, and often much resembling the shells of *Nucula*, *Cyrena*, &c.

Great numbers of the valves are spread over large surfaces of the flagstone, sometimes scattered sparsely, sometimes congregated in groups, forming films between the layers of the fissile stone. The valves are usually single; pairs, with their hinge-lines in juxtaposition, are rare. The specimens which I have are in dark-grey, tough, fine-grained, sandy

[1] In one or two instances I have been almost misled by apparently elongate valves, which are in truth, two valves pressed accidentally one on another "conformably," but still one extending a little beyond the other.

[2] Miller's 'Old Red Sandstone,' 1st edit., 1841, p. 99, pl. 5, fig. 7; 4th edit., 1850, p. 132, pl. 5, fig. 7; edit. 1858, p. 116; 'Cruise of the Betsey,' 1858, p. 415. Dr. J. G. Malcolmson, 'On the Relations of the Old Red Sandstone,' &c. (read in 1839), 'Quart. Journ. Geol. Soc.,' vol. xv. (1859), p. 351; Sir R. I. Murchison, Ibid., p. 404, 411, and 413; 'Siluria,' 2nd edit., 1859, p. 288; C. W. Peach, 'Trans. R. Geol. Soc. Cornwall,' 1855, p. 232.

[3] By Mr. S. P. Woodward, at the Meeting of the British Association at Liverpool, 1854.

flagstone, slightly micaceous, somewhat varying in tint and hardness. They usually appear to have a superficial smoothness or even gloss, and often a light-brown tint, with some degree of translucency. But the substance of the valve flakes off readily, leaving a film on each of the two surface-planes in a split stone; and it is comparatively seldom that a valve shows its real exterior; for, though the surface may sometimes come away from the stone in splitting, and leave a clean cast, yet an outer flake of the valve seems nearly always to have fallen away with the shock of the blow; and the sandy nature of the matrix is too coarse to retain traces of any very fine microscopic sculpturing in the cast or mould of the surface. Something like a regular sculpturing appears on some specimens, as we see in fig. 5; but this is too much interfered with by the pressure of the sand-grains to be taken for the true ornament.

In the Kirkwall specimen the valves are pyritized; but those from Caithness retain their brown horny tissue, although the outermost surface is seldom preserved, and only in little patches on some valves. From this circumstance it is very difficult to form a correct diagnosis of the species; for the superficial ornamentation yields important specific characters in this genus, and in this case it cannot be satisfactorily studied.

Mr. C. W. Peach, of Wick, has favoured me, at my request, with the following notes on the geological distribution of the Estheria membranacea:—

"The first place where they were discovered was Pickoquoy Quarry, near the Peerie (Little) Sea, at Kirkwall. I have got them there *in situ*. They are found in a thin bed,[1] and lie in great quantities on the surface-planes, never to any depth, but just, as it were, interleaved. Here, as well as at all the other localities, they are accompanied by scales of fish and pieces of bone (of *Dipterus*, &c.).

"They occur also at Marwick Head, near Skaill, Orkney; and were found there first by Mr. W. Watt. In 1857, I found them in a new locality in Orkney, at the farm of Chumley, between the manse of Sandwick and Stromness, in a small quarry opened to build the farm-house and buildings there. The matrix is coarse, rather soft, and pale-blue, but makes good building-stone. They were rare, and were accompanied with a few fish-scales, probably of *Dipterus*.

"At Thurso East, Mr. Dick has got them near the castle-residence of Sir George Sinclair, Bart. I have also seen them *in situ* there, but few fell to my lot. I saw portions of fish remains near them. Mr. Dick has also got them in great quantities at Murkle Bay, between Thurso and Castle Hill.

"At Castle Hill, under the house of Mr. Traill, M.P., they are very abundant (first found by Dr. Sutherland), in a good building-stone, of a similar colour to that of Thurso and Chumley—pale-blue, and soft to the touch; as also at Kirkwall, &c. At Castle Hill they are not in thick layers, but interleaved, and occur with Fish-remains and Coprolites, lying amongst and on them. Near this place, about 10 feet above the Estheria-beds, are

[1] Scarcely half an inch in thickness, according to Hugh Miller; see his description of the quarry, in 'The Cruise of the Betsey,' 1858, p. 415.

beds of limestone, varying from 2 to 6 or 8 inches in thickness. These are composed almost entirely of fragments of bones and scales of fishes (some 2 inches in length, others smaller), cemented together by carbonate of lime, which, when pieces of the rock are steeped in dilute acid, is dissolved out, leaving the fish-remains standing in relief.

"A small greenstone-dyke passes through the Estheria-beds; and not far distant the rocks have been disturbed, and a great bed of bituminous shale occurs, which burns with a bright white flame, and smells like fish-oil. The greenstone-dyke is not above 2 feet wide; it does not appear to have disturbed the strata. I have found other such dykes since, near John O'Groat's and the Island of Stroma; and I find that these must have broken through after the flag-beds had become consolidated, because in the two latter places portions of the flagstones are enclosed in a breccia-like state in the trappean matter.

"Near Wick, I have met with limestones similar to those above mentioned, enclosing fish-remains, which, however, are much smaller than those in the limestone of Castle Hill. Some are very minute, and, where the rock has been exposed to the weather, show thin fine lines of yellow in the broken edges. All these beds take that colour wherever exposed, although they are bluish or dark grey when first broken. If put into acid, they soon become yellow. I believe that I have the *Estheria* also with these broken fish-remains at Wick. Some of these thin beds of broken fish lie nearer the Estheria-beds at Castle Hill than the thick beds which I mentioned.

"All the Estheria-beds that I know are amongst the flag-beds of commerce; consequently, according to Sir R. Murchison's 'Siluria' (pp. 283, 432, &c.), they are in the middle formation of the Old Red Sandstone.

"Sir R. Murchison mentions them as being found in Shetland. A little shell-like fossil that I got on Sumburgh Head was much like one." [C. W. Peach, January 28, 1861.]

Mr. John Miller, F.G.S., of Thurso, has also supplied me with information respecting the local occurrence of these little fossils. He says—

"The *Estheria membranacea* was discovered by Mr. Robertson, of Inverugie (Elgin), in a quarry at the Peerie Sea, near Kirkwall, on the mainland of Orkney. The Orkney Islands are a prolongation of the Old Red Sandstone of Caithness, possessing a well-marked development of the triple arrangement characterising the Old Red series of the north-east corner of Scotland, as shown by Sedgwick and Murchison more than thirty years ago, and since confirmed by Sir R. Murchison in his various memoirs on the subject. The *Estheria* occurs in the middle member of the series, or the great fish-bed. Hugh Miller figured it as a molluscan shell in his well-known work, the 'Old Red Sandstone;' and shortly after that book was published Mr. Dick found the *Estheria* in Caithness, at various localities between Thurso and Murkle Bay, in the cliffs and shelving rocks of the sea-coast. I afterwards found it in the Brownhill Quarry, a little to the south-west of Thurso; and Mr. Peach has since found it at Castle Hill. From this last locality to Thurso

is about six miles. In Caithness, as in Orkney, it is only found in the middle member of the Old Red Sandstone, associated with *Asterolepis*, *Coccosteus*, *Dipterus*, *Diplopterus*, and *Osteolepis*.

"Of the vertical range of the *Estheriæ* it is difficult to speak, as all the localities in Caithness, alluded to above, are high up in the middle member of the Old Red series: if, however, quarries were opened lower down in this middle group, I venture to anticipate that the *Estheriæ* would still be found, as the same mineral conditions (calcareo-argillaceous flagstones, intercalated with sandstones,) persist almost from the top to the bottom of that group in Caithness, accompanied by the same characteristic fauna of Fishes, their scales being diffused throughout the strata in great abundance; and, as the *Estheriæ* have often been mistaken for the scales of *Dipterus*, I think it probable that many of those supposed scales may turn out to be the carapace-valves of the little Crustacean under notice." [J. Miller, February 4, 1861.]

The specimens of flagstone, bearing *Estheria membranacea*, that I have seen are as follow:—1. A black, micaceous, fine-grained flagstone, having a grey streak, and weathering olive-grey; the Estherian valves numerous, pyritous, iridescent under the microscope, and retaining no trace of the surface-ornament; accompanied with a coprolite-looking body. 2. From Thurso East, a greenish-grey micaceous flagstone, slightly calcareous; the valves numerous, preserving their tissue, but crumpled and broken. 3. From Murkle Bay, greenish-grey, micaceous, calcareo-argillaceous flagstone; the valves numerous, retaining here and there portions of their surface. As Hugh Miller has already observed,[1] the valves do not for the most part lie thinly and evenly scattered over the bedding planes of these hard laminated mudstones, but are clustered here and there in thickly set groups.

The valves occasionally retain their substance, and are then brown, opaque, and rugose; usually, however, a thin, smooth, shining, light-brown, horn-like film is all that remains.

Though the majority of existing and fossil *Estheriæ* have more or less oviform carapaces, with the umbo situated at or near the antero-dorsal angle, yet the position of the umbo at or near the centre of the dorsal line (as in *E. membranacea*) is not foreign to this genus; for *E. Hislopi*, Baird ('Zool. Proceed,' 1859, p. 232, Annulosa, pl. 63, fig. 1), from India has this condition; and *E. concentrica*, Bean, sp. (Pl. III, figs. 13—17) may be said to stand in the same category.

In July, 1859, Mr. J. W. Salter showed me some specimens (from Russia) of light-grey, very finely grained arenaceous clay, containing an *Estheria* apparently identical with *E. membranacea*, labelled "*Asmusia membranacea*, R. Pacht; with traces of *Lingula bicarinata*,[2] Kutorga; Kokenhusen." Dr. Pander has also favoured me with some specimens from Kokenhusen. These are identical with the *Estheriæ* from Caithness.

[1] 'Cruise of the Betsy,' p. 415.

[2] *Lingula bicarinata* is figured and described by Kutorga, in his 'Beiträge zur Geognosie und

The Livonian specimens are well preserved in their impalpably fine-grained matrix; they are much flattened, of a dull honey-colour, and beautifully neat in their graceful outline and their delicate concentric ridges (Pl. I, fig. 6). Like the Caithness specimens (Pl. I, figs. 1—4), they are almost symmetrically semicircular on the front, ventral, and hinder borders, and straight along the whole dorsal line, except where the umbo slightly protrudes somewhat in front of the centre. The outline is somewhat quadrate, with a slight obliquity, due to the eccentric umbo being the starting point of the conforming concentric ridges. The fulness of the curves of the ridges and of the ventral border are somewhat hindwards; the ridges being closer together on the anterior than on the posterior portion of the valve.

The well-preserved condition of the carapace-valves enables us to recognise about thirteen concentric ridges; and in some specimens a few fainter intermediate striæ are seen under the microscope. The coarse rounded wrinkles of the specimens in the Caithness sandy flagstones are the rough modifications of this delicate structure; either the ridges being squeezed up and distorted, or, in some cases, the intermediate hollows having been swollen up by the wrinkling pressure of the sandy matrix (figs. 2, 3, and woodcut, p. 22).

In the Livonian specimens, the interspaces between the ridges appear to be delicately sculptured with faint transverse wrinkles (fig. 7). This is in strong contrast to the coarsely granular appearance of the Caithness specimens (fig. 5), which have probably been impressed with the sand-grains of the matrix.

Asmusia membranacea, Pacht, is mentioned by Dr. Ch. Pander in his memoir 'Ueber die Saurodipterinen, Dendrodonten, Glyptolepiden, und Cheirolepiden des devonischen Systems' (St. Petersburg, 1860, p. iv), as being found in a greyish, laminated, calcareous marl, with intercalated grey and bluish clays, both full of Devonian fish-remains, on the River Torgel, in Livonia; but I was not aware that it had been figured and described until I received Dr. Ch. Pander's communication in November, 1861. (See p. 21). Of Kokenhusen, the locality above mentioned for *A. membranacea*, we have the following particulars in the 'Geology of Russia,' &c., by Murchison, De Verneuil, and Von Keyserling (p. 51):

"The picturesque rocks in the environs of the Castle of Kokenhusen [in Livonia] particularly deserve notice, not merely on account of the thickness of the vertical section[1] (speaking, of course, by comparison), but specially because the beds contain Ichthyolites.

Palæontologie Dorpats,' &c., 1835—37 ('Verhandl. d. min. Gesellsch. zu St. Petersburg,' 1846, p. 110, pl. 7, fig. 12); and is also described in Eichwald's 'Lethæa Rossica,' livr. 6, p. 921. It occurs in the Old Red Sandstone series, near Dorpat, in Livonia, on the borders of the River Oredège, near Gatschina, and in the micaceous argillaceous limestone co-ordinated with the Old Red Sandstone, at Sivoritzy, near Gatschina, in the Government of St. Petersburg. *Lingula* also accompanies *Holoptychius* and *Pterichthys*, in Devonian marls and sandstones, underlying the Coal-measures, in the Gouvernement Nowgorod, on the Prykscha, near Scherechowitschi. (G. von Helmersen, 'Mém. Acad. Imp. Sc. St. Petersb.,' vol. iii, No. 9, p. 22, 1860.

[1] In the Index to the 'Geology of Russia,' &c., the word "vertical" before "Devonian beds containing Ichthyolites" should be erased, as the beds are almost horizontal.

The little River Pehrse, which there empties itself into the Düna, runs in a deep gorge, in which many beds of impure concretionary limestone are seen to alternate with courses of calcareous shale or marl. These alternating strata, occupying a thickness of about 100 feet, repose on a band of arenaceous limestone, distinguished by impressions of fucoid-like or polypiform bodies, and beneath it is a bed of concretionary limestone with marly limestone, in which are remains of *Ctenacanthus serrulatus* (Ag.) and *Osteolepis*, &c., both of which genera occur in the Old Red Sandstone of Scotland."

The marls of Kokenhusen are referred to by Col. G. von Helmersen, in a work on the geology of the central parts of Russia.[1]

At p. 71, he says :—" The Devonian formation towards the east (as far as is known to me) consists of the same dolomites, calcareous beds, and marls, as occur near Kokenhusen, of which on the Schelon only the lower member is conspicuous, and particularly the marls are much developed." The marl, he says at pp. 72 and 73, is " one of the lowest beds of all the Devonian calcareous strata; it is characterised at places by *Spirifer Anossoffi*, *Sp. Archiaci*, *Orthis crenistria*, *Murchisoniæ*, *Euomphalus Voroneiensis*, corals, and some few fish-remains. On the Dwina, a similar bed appears to correspond with this blue marl; it contains, besides very numerous fish-remains, only *Lingula bicarinata* and *Posidonia* (*rugosa*, Kut.). It rests immediately on the sandstone of the Devonian formation, which, so largely developed in Livland, is altogether wanting on the Don and Woronesh." At pages 41, 44, &c., Von Helmersen also gives sections seen at Mzensk, Jefremow, &c., where the marls are intercalated with limestone, and rest on a limestone that has *Spirifer Anossoffi*, *Serpula*, *Nucula*, corals, and some fish-remains.

On the River Torgel, in Livland, Dr. Pander found that the hard white sandstone, used for grindstones, contains fine remains of *Asterolepis* (Pander), and that the overlying bluish marls and clays contains scales and teeth of *Osteolepis*, *Dipterus*, and *Glyptolepis*, in company with the *Asmusia membranacea* of Pacht. ' Ueber d. Saurodipt,' &c., 1860, p. IV.

Through the kind intervention of Col. G. von Helmersen, I have been favoured with the following bibliographic history of *Asmusia membranacea*, drawn up by Dr. Ch. Pander, the eminent palichthyologist, who has taken much interest in this species, has himself recognised its crustacean character, and has courteously favoured me with some specimens from Kokenhusen :

[1] ' Geognostische Untersuchungen in der mittleren Gouvernements Russlands, zwischen der Düna und Wolga, in der Jahren, 1850 und 1853, ausgeführt von G. v. Helmersen und R. Pacht.' [Including R. Pacht's ' Geognostische Untersuchungen zwischen Orel, Woronasch, und Simbirsk im Jahre, 1853.'] Herausgegeben von G. v. Helmersen. Gedruckt auf Verfügung der Kaiserlichen Akademie der Wissenschaften. (' Beitrage zur Kenntniss des Russischen Reiches und der angränzenden Länder Asiens,' 21. Bänchen.) 8vo, St. Petersburg, 1858.

In this work are included some of the results of the labours of that promising young geologist and traveller, Raimund Pacht, above named, who, we regret to learn, from Col. von Helmersen's Introduction to the ' Geogn. Untersuch.' died in 1854, at the early age of thirty-one.

"In the marls near Kokenhusen on the Pehrse, which lie on the lowest Devonian sandstone, form the lowest member of the Devonian limestone, and are particularly rich in the remains of *Osteolepis*, *Diplexus*, *Asterolepis*, &c., occur little bivalves, often in immense quantities, which Eichwald, in his 'Geognosie von Russland,' published (in the Russian language) in 1846, p. 339, referred to *Posidonomya*.

"Pacht, unaware of this determination, formed of these bivalves a new genus, which he called *Asmusia;* and the species, on account of the thinness of the shell, he called *membranacea;* 'Der devonische Kalk in Livland,' 1849, p. 44.

"Afterwards, finding that this animal had been already referred to *Posidonomya*, he gave up his new genus, in his memoir 'Ueber *Dimerocrinites oligoptilus*,' 1852, p. 26, and kept the name *Posidonomya*. In the same year this species appeared as *Posidonomya rugosa* in Kutorga's 'Geognostische Karte des Gouvernements von Petersburg,' and as *Posidonomya membranacea* in Pacht's new edition of his 'Der devonische Kalk in Livland,' 1859, p. 44, where it is accurately described, and illustrated by fig. 7 on the plate accompanying his memoir, but not with exactness.

"On account of Rupert Jones's researches on *Estheria minuta* in 1855, by which I was made aware that *Posidonomya minuta* of the Trias is a Crustacean, I examined carefully under the microscope this so-called *Posidonomya*, and found clearly that its tissue corresponded, not to that of the *Acephala*, but to that of the *Crustacea*. I considered, however, judging from its outer form, that this creature could not be allied to *Estheria*, from which it differs by its straight hinge-border; and I was therefore uneasy in retaining for it the name given by Pacht. In this mind I have treated of *Asmusia membranacea* as a Crustacean, and not as an Acephalous Mollusc.

"This animal is clearly identical with that figured by Hugh Miller in his 'Old Red Sandstone,' pl. v, fig. 7. Should this be the case, it would, as I have formerly indicated, contribute much to the correlation of the Caithness shales, so rich in fish-remains, with the marls of Kokenhusen, which have an equally rich ichthyological fauna."[1] [Christian Pander, $\frac{27\ \text{Oct.}}{8\ \text{Nov.}}$, 1861.]

Asmusia membranacea from the sandy clay of Kokenhusen, is the same as the *Estheria* from the harder and more coarsely grained flagstones of Caithness. In the fine-grained deposit of Kokenhusen, the shell is very thin and of a light amber-colour, and being much less affected by the pressure of sand-grains, though often much crumpled, exhibits here and there faint traces of a regular ornament of a vertical wrinkly reticulation between the ridges (fig. 7). Owing to the difference in the matrix and mode of preservation, in the Russian specimens, the thin upstanding concentric riblets, are better preserved than in the flagstones of Caithness, and therefore form a prominent feature, which in the

[1] A neatly executed sketch, in water-colours, of the Kokenhusen fossil has been kindly communicated to me by Dr. Pander (through Col. von Helmersen), agreeing very closely with our fig. 6 (drawn under the *camera-lucida*), but showing eighteen, instead of about fourteen ridges. The sketch also indicates the shorter and the longer varieties of form, such as we have observed among the specimens from Caithness (compare figs. 2 and 3).

other case is replaced by a modification of the ridges and broad intervening furrows, which are squeezed up into rounded wrinkles (see woodcut, fig. 1).

Fig. 1.
Diagram showing the relative position of the Ridges and Interspaces in the shell of the Estheria.

a. Section of the Ridges and Interspaces in a fresh carapace-valve.

b. In some fossilized valves, the Interspaces are squeezed up, leaving the Ridges in between.

c. In other specimens the Interspaces are depressed when the shell is crumpled, and the Ridges are irregularly upraised.

Not being as yet able to discern any essential difference between the carapace-valves of the recent *Estheriæ* and the fossil from Kokenhusen and from Caithness, I do not think that the generic term "Asmusia" is required.

I cannot find that the term "membranacea" (belonging to a Wealden *Cyclas*) has been specifically applied to an *Estheria* of the Wealden, though often misapplied in collections; and I cannot substantiate the remark I made on that point in 1859 ('Quart. Journ. Geol. Soc.,' vol. xv, p. 406). The term "membranacea" remains, therefore, for R. Pacht's species before us.

Habitat of Estheria membranacea.—In the Estherian flagstones of Caithness we have no evidence of any marine characters, nor does their being associated with some thousand feet of sandstones and conglomerates render it impossible that they themselves should have been formed in fresh or brackish water. The occurrence of the fishes of the Old Red series of Caithness in Russian deposits with marine shells does not necessarily prove the marine nature of these Fishes, which may have had freshwater habitats, but have been hurried out to sea by floods; or, indeed, may have lived both in salt and in fresh water periodically. On the other hand, the "traces of *Lingula bicarinata*," in the Estherian sandy clay of Kokenhusen, point, at first sight, towards marine conditions. They may, however, have been "derived" fossils—fragments washed out of some older formation; or the *Estheriæ* may have been brought by flood or freshet low down the old estuary towards the habitat of the *Lingulæ;* or the *Lingulæ* may have had temporary lodging there whilst the sea held the estuary at times; or they may both have lived in brackish water: for we shall find further on, in the history of *Lingula tenuissima* of the Muschelkalk, some evidence of its having become subjected to such conditions. The same may be said for the fish-bed, with *Lingula* and "Posidonia," on the Dwina, mentioned by Helmersen (see p. 20).

On the Torgel (p. 20), fishes only are the associates of the "Asmusia;" and these cannot be regarded, in the present state of knowledge respecting them, as direct evidence either of the freshwater or the marine character of the deposit. In fact, their existing congeners, whether Polypterids or Silurids, affect lakes and rivers.

Note.—Since Mr. C. Peach wrote to me in 1861 on the subject (p. 17), he has found *Estheria membranacea* in three other quarries in the parish of Wick. The first is near the blacksmith's shop, Kilmster; the second is about a mile beyond this; and the third is near the halfway-house between Wick and John-o'-Groats. The distance between the first and last quarry is at least four miles, and this not in the line of strike of the beds. *Dipterus, Diplopterus, Osteolepis, Glyptolepis,* and *Coccosteus,* with land plants, are also found in these quarries.

2. Estheria striata, *Münster*, sp. Pl. I, figs. 8—18.

Sanguinolaria striata, *Münster and Goldfuss*. 1826, Petref. Germaniæ, II, p. 280, pl. 159, fig. 19.

Cardiomorpha striata, *De Koninck*. 1842, Anim. Fossil. Ter. Carbonif. Belgique, p. 105, pl. H, fig. 9, *a*, *b*, *c*.

Amongst the many fossil Bivalves of the Upper and Lower Carboniferous strata there are several that more or less resemble small Unios; and these have been subjected to much change of nomenclature. One of the smallest and thinnest of these, usually represented by a mere impression, though occasionally a film of carbonate of lime has replaced the shell, is *Sanguinolaria striata* of Münster, from the Mountain-limestone series of Regnitzlosau, near Hof, Bavaria. This was figured and described by Goldfuss; and again described and illustrated by De Koninck, who found it in the carbonaceous shales of the Mountain-limestone of Visé, Belgium. Being able to recognise the umbonal area of the closed valves,[1] De Koninck referred this fossil to his genus *Cardiomorpha*.

I have seen numerous specimens of this fossil from several localities, and from different horizons of the Carboniferous system of strata. Frequently they appear as conspicuous black and shiny impressions on the dark-coloured shales; sometimes they are obscure and dull; not unfrequently there are compressed casts of the bivalve; occasionally the thin shell has been converted into carbonate of lime; or a rusty film may sometimes represent the shell; usually the two valves have been only slightly displaced (Pl. I, fig. 9). The very numerous concentric striæ on these fossils is a striking feature; also the absence of relatively large, concentric, rounded ribs among these striæ, though some of the latter stand out stronger than the others, and at nearly regular distances apart (figs. 10, 12, 14). Compared with those shells of small *Aviculæ*, *Posidonomyæ*, and *Anthracopteræ*,[2] that have been wrinkled by pressure, the fossils under notice characteristically differ, by being less subject than the former to coarse and irregular transverse wrinklings. In one instance (in the shales from Lammerton, Berwickshire) we have some trace of structure in the film representing the shells (figs. 16, 17); by this fact, together with the Estherian character of the crowded striæ (a feature not unusual in *Estheriæ*; see Pl. II, figs. 28—31; Pl. III, figs. 6, 13, 23; Pl. IV, figs. 1—3), I am induced to regard these little fossils as remains of *Estheriæ*; and their tenuity, their gregariousness, and their association with fish-remains,[3]

[1] De Koninck states that he saw the "hinge:" I doubt that he means the hinge itself (which is said to be edentulous in *Cardiomorpha*, having only a narrow ligamental furrow, and an obscure internal cartilage-groove); but he probably refers to the collocated umbos represented in his fig. 9 *b*.

[2] Mr. Salter's name for the *Myalinæ* of his "Notes on the Fossils of the Iron-stones of South Wales," 'Geol. Surv. Mem.,' 1861.

[3] The occurrence of Bivalved Entomostracans in company with fish-remains is frequent in the fossil state, and agrees with the known habits of these animals. The *Entomostraca*, like other *Crustacea*, act as scavengers among dead molluscs and fishes; and are an important article of food to many fishes.

favour this view. Moreover, there are smaller *Estheriæ*[1] in the Carboniferous strata, showing their characteristic features (Pl. II, figs. 39, and Pl. V, figs. 1—7) more clearly, just as the small *Estheria elliptica* of the Wealden (Pl. IV, figs. 6, 7) exhibits a sculptured ornament, whilst the larger specimens have the surface obscured by thickly set striæ (figs. 1—5). *E. striata*, also, like other *Estheriæ*, has subquadrate individuals (see p. 11).

Estheria striata may be thus characterised:

Carapace-valves thin, nearly oblong, but somewhat higher at the posterior third than anteriorly; umbo distinct, placed forward, being situated at the antero-dorsal angle, beyond which the convexity of the anterior border projects but slightly; posterior border boldly rounded, usually more or less elliptical and oblique; ventral border gently and obliquely convex. The surface of the valves presents numerous concentric wrinkles (30—50 or more), some of which appear to be the raised ridges usual in *Estheriæ*, and the others are due to finer intermediate striæ (figs. 10, 12, and 14). The surface is frequently found to be wrinkled transversely (as in figs. 10 and 14) with very delicate corrugations crossing the concentric ornament, and due to mechanical causes. Coarser wrinkles, also due to the crumpled state of the fossil valves, are often seen (as in fig. 12); the latter seem to affect the inner portion of the shell, which (as we see by figs. 16 and 17) sometimes shows a cellular appearance analogous to the reticulate structure of crustacean shell. This reticular tissue is found freely dispersed on the shale from Lammerton, over some portions where but little other trace of the Estherian valve itself remains. Where the boundaries of the meshes make strong lines parallel with the concentric lines of growth of the shell (as in fig. 17), the fine intermediate striæ of the surface would probably be stronger than where the reticulation is irregular, as in fig. 16.

Of *E. striata* I have seen numerous specimens from several different localities; namely,—1. From Lammerton, Berwickshire; in bituminous shales belonging to the Mountain-limestone series. 2. From the Lanarkshire coal-field (in cannel-coal). 3. From Silesia, in carbonaceous shales of the Lower Coal-measures. 4. From two places in Lancashire, in cannel-coal of the Middle Coal-measures, and in bituminous shale of the Lower Coal-measures. 5. From near Chesterfield, Derbyshire, in carbonaceous shale of the Lower Coal-measures.

Differences of outline are to be observed among the various individuals; and some of these variations appear to be limited to one or other of the groups of specimens from the five localities mentioned. It is convenient, therefore, to seize these distinctions, slight as they are, and certainly not of specific value (nothing of the body and limbs of animals remaining to help our judgment), and make them serviceable in the recognition of the several very similar forms of carapace from widely separate places, and from at least four distinct horizons in the Carboniferous group of strata.

[1] As the smaller specimens are not found in company with the larger *E. striatæ*, I have kept them specifically apart. Were it otherwise, no distinction of great value could be easily described, and they might be regarded as young forms.

ESTHERIA STRIATA, Var. BEINERTIANA. Pl. I, figs. 11—14.

Inch.		Inch.	
Height of valve, $\frac{1}{6}$ Length, about $1\frac{1}{6}$	Proportion 3 to 5, or 1 : $1\frac{1}{2}$ +	Height..... $1\frac{1}{6}$ Length nearly $\frac{2}{6}$	Proportion 2 to 3, or 1 : $1\frac{1}{2}$.

Carapace-valves obliquely subovate; posterior half much higher than the anterior; postero-ventral angle produced, with an oblique elliptical outline.

This is very similar to the figures of *Estheria (Cardiomorpha) striata* given by Goldfuss and De Koninck.

1. Figs. 11, 12. This specimen is in hard black shale from Shaly Brow, not far from Wigan, and near Rainford and Billinge, Lancashire; collected by Mr. E. W. Binney, F.R.S., F.G.S., at the pit's mouth (see page 29, for the position of this shale in the Lower Coal-measures).

2. Figs. 13, 14, are taken from specimens crowded on the surface-planes of a dark-coloured, hard, stony shale, belonging to the Lower Coal-measures, and from the 21st level of the Rudolph Pit at Volpersdorf, near Neurode, in the Duchy of Glatz, Silesia.[1] These *Estheriæ*, from the lowest of the Silesian coal-beds, were found by the able geologist and botanist, Dr. Beinert, of Charlottenbrunn, who has carefully studied the Coal-measures of Waldenburg and Glatz; and they were communicated to me by our mutual friend, Dr. H. B. Geinitz, of Dresden, in 1859.

3. This variety has also been found by Mr. Binney in Mr. Hulton's cannel-coal, at Hulton Lane-ends, near Bolton-le-Moors, *Estheriæ* lying in numbers on one surface-plane; and fragments of a similar shell have been found in the cannel-coal at Moss House, two and a half miles S.W. of Bolton (Mr. Salter). I have also seen, from Mr. Binney's collection, this *Estheria* in cannel-coal from Ince, near Wigan, on two surface-planes two inches apart. According to Mr. Binney, it is always associated with remains of Fishes of the genera *Megalichthys*, *Rhizodus*, *Holoptychius*, *Cœlacanthus*, and *Palæoniscus*, as well as of Placoid Fishes. Mr. J. Rofe, F.G.S., also has given me a specimen of Wigan cannel containing a band of this *Estheria*, associated with a Fish-tooth. This specimen was from the middle of a two-foot bed of cannel, the top of which is covered by a layer of Fish-remains, about an inch thick. In this instance, some of the carapace-valves are represented by very thin films of whitish carbonate of lime, having the striated pattern of the impressions.

4. Another occurrence of this, or a closely allied, variety is indicated by a specimen of cannel-coal (bearing numerous *Estheriæ* on one surface-plane, and grey fish-scales on another, half-an-inch distant), from Carluke, Lanarkshire, which was collected by Mr. Binney, on a pit-bank, where a coal lying just above the Mountain-limestone series was being worked.

[1] Some of the coal-beds of this district have been fully described by Beinert and Goeppert in the 'Nat. Verhand. Holland. Maats. Wetens. Haarlem,' vol. v, part 2, 1849.

ESTHERIA STRIATA, Var. TATEANA. Pl. I, figs. 15—18.

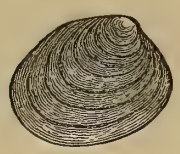
Inch.		Inch.	
Height of valve, $\frac{1}{6}$	Proportion 2 to 3, or 1 : $1\frac{1}{2}$	Height ..... $\frac{1\frac{1}{2}}{12}$	Proportion 5 to 7, or 1 : $1\frac{1}{2}$—.
Length ..... $\frac{1\frac{1}{2}}{6}$		Length ..... $\frac{2\frac{1}{2}}{12}$	

Height, nearly..... $\frac{1}{10}$ inch
Length, more than $\frac{1}{10}$ „ } Proportion 11 to 14, or 1 :1 +.

Carapace-valves nearly oblong, but higher at the posterior third than anteriorly, boldly rounded behind with a semicircular outline, obliquely rounded in front. Fig. 18 represents a shorter carapace than fig. 15; and some appear to have been even shorter, and of a more rounded form, than this. We have a corresponding occurrence of oblong or subovate, in company with subquadrate, forms of Estherian carapace in the case of the Rhætic *E. Mangaliensis* of India (Pl. II, figs. 16 and 20), and the Wealden *E. elliptica* (Pl. IV, figs. 1 and 3). The outlines of the specimens figured may have been slightly altered by pressure, but they are far more perfect than the majority of those I have seen from Lammerton.

FIG. 2.

Sketch of a subquadrate individual of Estheria striata, *from Lammerton, Berwickshire.*



(Magnified 6 diameters.)

The specimens of *Estheria striata*, var. *Tateana*, were kindly submitted to me by their discoverer, Mr. George Tate, F.G.S., of Alnwick, some years since. They are numerous, but obscure, occurring either as impressions or as thin rusty films, or as a faint reticulate tissue, in a black and somewhat bituminous shale. They seem to have been originally densely crowded; and are associated with Fish-remains, *Spirorbis carbonarius*, and impressions of Plant-stems. The shale belongs to the Mountain-limestone series, and comes from Lammerton, in Berwickshire.

To render the geological position of these *Estheriæ* quite plain, Mr. Tate has obliged me with a succinct account of the strata and fossils observed by him in the section where these shales are met with. He says—

"The dark carbonaceous shale containing *Estheriæ* is exposed in the cliff along the Berwickshire coast for upwards of a mile; it is accessible, however, only at a few points; and *Estheria* has apparently but a limited distribution in the bed. I have found it only near Lammerton. The section here, is as follows (in descending order):—

		Feet.	Inches.
1.	Reddish sandstone	90	0
2.	Dark carbonaceous shale, with *Estheriæ;* where thickest, it is generally hard and flaggy	12	0
3.	Limestone, fossiliferous; usually of a dun colour, and weathering buff	4	0

		Feet.	Inches.
4.	Coal, not exceeding	0	7
5.	Fire-clay, with Stigmarian rootlets	5	0
6.	Reddish sandstone; many of the beds thin and slaty	30	0
7.	Shales, with a little poor ironstone	4	0
8.	Coal (irregular)	0	10
9.	Yellow sandstone	4	0
10.	Drab, slaty sandstone, passing into argillaceo-arenaceous shale	10	0
11.	Arenaceous shale, slightly calcareous	3	0

"These beds dip east by south; all of them belong to the Mountain-limestone group, though they are not far from its base.

"No. 1. This sandstone is overlain by many beds of limestone, and associated with sandstones, shales, and coals, which form the mass of the Mountain-limestone group, extending into Northumberland.

"No. 2. The Estherian shale. This contains another Entomostracan form.[1] There are also a number of broken fragments of plants; the most numerous being reed-like stems, longitudinally ribbed, but without joints, *Coniferites verticillatus* (Tate[2]), and *Sphenopteris Johnstoniana* (Tate[3]). Attached to the plant-stems are species of *Spirorbis*. Scales of Ganoid Fishes are abundant; and I have determined teeth and scales of *Holoptychius Hibberti* in this shale. In the lower part of the deposit I found *Chonetes sordida* and *Nucula gibbosa*. This bed, taken in connection with that below it, shows changes of conditions from marine to estuarine, and probably to fresh water.

"No. 3. This limestone is very fossiliferous, containing—

Strophomena analoga.
Productus giganteus.
Productus semireticulatus.
Lithodendron junceum.
Lithodendron affine.
Lithostrotion Portlocki.
Stenopora tumida.
Favosites parasitica.
Astræopora cyclostoma.
Syringopora geniculata.
Aulopora gigas.[4]

"No. 10. In the arenaceous shales I have found *Lingula squamiformis*, and an elongated form allied to, but which may be different from, *Lingula mytiloides*.

"No. 11. Here occurs *Discina nitida*. In several of the beds of Nos. 10 and 11 are many Annelid-borings.

"In arenaceous shales a few yards below the above section, I have found *Sanguinolites arcuata*, *S. carbonaria*, *Aviculo-pecten Pera*, and *Spirifer laminosus*." [G. Tate, February 9th, 1861.]

[1] See Appendix.
[2] 'Fossil Flora of the Eastern Border,' p. 309.
[3] Ibid., p. 306.
[4] 'Transact. Berwickshire Nat. Club,' vol. iv, p. 152—154.

ESTHERIA STRIATA, Var. BINNEYANA. Pl. I, figs. 8—10.

Height of valve, $\frac{7}{12}$ inch
Length..... 1 „ } Proportion 7 to 12, or 1 : $1\frac{3}{4}$ —.

Carapace-valves oblong; upper and lower margins nearly parallel; ends slightly rounded; three times as large as the other varieties; attaining a length of one inch. The largest recent *Estheria* that I know (*E. Melitensis*) is scarcely more than half an inch long.

In black, laminated, carbonaceous shale: specimens numerous on the planes of bedding. Found by Mr. E. W. Binney, at an ironstone-pit at Lowndsley Green, near Chesterfield, Derbyshire. This Estherian shale lies between the Winn-Moor Coal, below, and the Black Shale or Silkstone Bed above, a distance of about 70 yards.

To illustrate the geological position of the English specimens of *Estheria striata*, Mr. Binney has supplied me with a section of the strata of the lower part of the Middle, and the whole of the Lower Coal-measures of Lancashire. In a paper on the Permian beds of the North-west of England,[1] he has described all the divisions of the Lancashire Coal-field, Upper, Middle, and Lower; and a still more detailed account of the last may be found in another paper by him, on some Trails and Holes in some of the Carboniferous strata, and on *Microconchus carbonarius*.[2]

"The following section of the Coal-measures of Lancashire, in a descending order, commences with the strata just above the 'Wigan Cannel,' a 'mine' about 220 yards above the 'Arley Mine' of Wigan, or 'Silkstone Coal' of Yorkshire, the lowest coal of the Middle Field.

	Yds.	ft.	in.	
"Dark-grey shale	2	0	3	Contains *Megaphyton distans, Ulodendron majus,* and other coal-plants.
Black bass and inferior cannel-coal ...	2	0	6	The basses and cannels contain, in addition to *Estheria*, fishes of the genera *Megalichthys, Rhizodus, Holoptychius, Cœlacanthus,* and *Palæoniscus,* as well as remains of numerous Placoid fishes, generally found associated in Lancashire with the so-called *Unionidæ,* but in Scotland (at Charlestown) found with *Productæ, Spiriferæ,* and such marine shells.
Coarse cannel.....	0	0	2	
Good cannel (with *Estheriæ*[3])	2	2	0	

[1] 'Mem. Lit. Phil. Soc. Manchester,' 2d series, vol. xii, p. 209, &c. 1855.

[2] Ibid., 2d series, vol. x, p. 181, &c. 1852. Mr. Binney also refers me to the Report to the Home-Secretary, for the year ending 1858, by Mr. Joseph Dickinson, F.G.S., one of H. M. Inspectors of Coal-mines, as containing a good series of sections of the Lancashire Coal-field. In his 'Coal-fields of Great Britain,' and in the 'Memoirs of the Geological Survey of Great Britain, 1860,' Mr. E. Hull, F.G.S., has supplied some useful information respecting the same Coal-field. See also the 'Geol. Survey Map,' Sheet 89 S.E., and Explanations.

[3] From Hulton Lane Ends, and Ince Hall, near Wigan (Mr. Binney and Mr. Rofe).

		Yds.	ft.	in.	
	Earth	0	0	9	
King-coal.	Coal	0	0	8	
	Bass	0	0	8	
	Coal	0	2	0	
	Bass	0	2	0	
	Coal	0	1	6	
	Grey warren earth	6	2	0	
	Various strata and coal	214	0	0	
	Arley coal	1	1	0	
	(*Bottom of the middle portion of the Coal-measures.*)				
	Strata	5	0	0	
	Coal	0	0	3	
	Strata	30	0	0	
	Coal	0	0	3	
	Strata	53	0	0	(This is the horizon to which the *Estherian shale* found at Lowndsley Green, Chesterfield, belongs; see p. 28.)
	Coal	0	0	2	
	Strata	68	0	0	
	Coal	0	0	3	
	Strata	57	0	0	
	Coal	0	0	6	
	Strata, estimated about	80	0	0	The lower part, forming the roof of the coal, sometimes contains *Aviculo-pecten, Goniatites*, &c. *Estheriæ ?* (See below.)
	Forty-yards Coal	0	1	6	
	Strata	34	0	0	
	Upper Foot Coal, with balls	0	1	0	*Aviculo-pecten, Goniatites*, &c., in the roof.
	Strata	12	0	0	
	Ganister Coal	0	0	0	*Aviculo-pecten, Goniatites*, &c., sometimes occur in the roof; and often, shells resembling *Lingula, Modiola*, &c.
	Strata	16	0	0	
	Lower Foot Coal, or Spanish-juice Coal	0	1	6	
	Strata	16	0	0	
	Bassy Coal, or Salt's Coal	1	0	2	*Aviculo-pecten, Goniatites*, &c., in the "roof" sometimes; but generally shells of *Unionidæ* (?), with fish-remains: also *Cypridæ*, with *Microconchus carbonarius*, in some of the roof-shale; also *Estheriæ*.[1]
	Strata	40	0	0	
	Coal	0	0	9	*Aviculo-pecten* and *Goniatites*.
	Shales	4	0	0	*Aviculo-pecten* and *Goniatites*, sometimes.

[1] Mr. Binney thinks that the Estherian shale of Shaly Brow is from this roof; but some other geologists think that it is from the roof of the Forty-yards Coal above.

	Yds.	ft.	in.	
"Rough Rock" of the Lancashire geologists, "Upper Millstone-grit" of the Geological Surveyors	6	0	0	
Sand-delph Coal, or Feather-edge Coal.	0	1	6	The roof is generally a grit-stone; but at Birtle Dean, near Bury, it is a shale with *Aviculopecten*, &c.
Rough rock	20	0	0	
Lower flags and shales	120	0	0	
Coal	0	0	6	*Aviculo-pecten, Goniatites*, &c.
Shale	2	0	0	
Coal	0	0	8	
Black shale	8	0	0	
Black shale and sandstone	6	0	0	
Coal	0	1	3	
Shale	4	0	0	
"Upper Millstone-grit" of the Lancashire geologists	60	0	0	
Dark shale	40	0	0	
Coal	0	0	4	
Dark shale	15	0	0	
Coal	0	0	8	
Dark shale	6	0	0	
"Lower Millstone-grit," with its partings	130	0	0	
Limestone-shale, containing beds of grit-stone	300	0	0	[E. W. Binney, Feb. 7, 1860.]

Habitat of E. striata.—With regard to the possibly freshwater or marine character of the *Estheria striata*, above treated of, as indicated by its associates, I can only say that, excepting the occasional proximity of those dubiously marine forms, the *Anthracosiæ* and *Anthracomyæ*, and the presence of *Spirorbis* at Lammerton, sea-shells are wanting in the shales and cannel-coal in which this *Estheria* has been found.

In the 'Lethæa Rossica,' livr. vi, 1859, p. 90, Mr. Eichwald describes under the name of "*Posidonomya minuta*, Goldfuss," what may prove to be an Estherian fossil from shale apparently belonging to the Carboniferous Formation, near Izoume, in the government of Kharkof." It measures 1—1$\frac{3}{4}$ line in one diameter, and 1 line in the other. The valves are described as being horny, deep-brown, oblique, very thin, and very small; rather broader than long, rounded on the inferior border, nearly straight on the superior, and without an anterior ear; surface wrinkled with concentric (8—10) ridges, somewhat deep, unequal, concentric to the umbos, which are scarcely distinguished.

3. Estheria tenella, *Jordan*, sp. Plate I, figs. 26, 27; Pl. II, fig. 39; and Pl. 5, figs. 1—7.

Posidonia (?), *Michelin*. Bullet. Soc. Géol. France, 1836, vol. vii, p. 321.
Cypris, *A. D'Orbigny*, 1845; *Landriot*. Ibid., 2d series, 1849, vol. vi, p. 90.
— *Naumann*. Ibid., 2d series, 1848, vol. v, p. 301.
Posidonomya tenella, *Jordan and H. G. Bronn*. Neues Jahrb. f. Min., 1850, p. 577.
[? Estheria exigua, *Eichwald*, sp. See p. 37].

From the Murgthal and from Astley (Lancashire)	Height of valve, less than $\frac{1}{12}$ inch Length, rather more than $\frac{1}{12}$ „	Proportion 5 to 7, or 1 : $1\frac{1}{2}$—
From Bradford (Lancashire)	Height, more than $\frac{1}{12}$ „ Length, less than $\frac{1\frac{1}{2}}{12}$ „	„ 13 to 17, or 1 : $1\frac{1}{3}$—
From Oschatz	Height $\frac{1\frac{1}{2}}{12}$ „ Length, less than $\frac{2}{12}$ „	„ 8 to 11, or 1 : $1\frac{1}{2}$—
From Lanarkshire	Height, less than $\frac{3}{24}$ „ Length, less than $\frac{4}{24}$ „	„ 17 to 23, or 1 : $1\frac{1}{3}$+
From Bradford (Lancashire)	Height $\frac{3}{24}$ „ Length, more than $\frac{4}{24}$ „	„ 9 to 13, or 1 : $1\frac{1}{2}$—
From Bradford (Lancashire)	Height, more than $\frac{3}{24}$ „ Length $\frac{5}{24}$ „	„ 21 to 30, or 1 : $1\frac{1}{2}$—

Carapace-valves broadly subovate, oblong, or nearly quadrate; hinge-line straight, but rounding off before and behind insensibly into the well rounded extremities, which are nearly symmetrically, but unequally, curved. The umbo is forward, at the front end of the hinge-line, and does not interfere with the outline of the valve. Concentric ridges about 15; interspaces minutely pitted by the meshes of a delicate reticulation.

This *Estheria* occurs at several localities, and is essentially a member of the "Carboniferous" fauna, though it is found also in beds referred by some to the Permian formation (Oschatz, Autun, and ? Russia).

1. In the 'Neues Jahrbuch f. Min.,' &c., 1850, p. 577, Prof. H. G. Bronn gives an account of the black shales of Sulzbach, Lebach, &c., and describes *Posidonomya tenella* (Jordan) which there occurs in company with the interesting crustacean *Gampsonyx fimbriatus*[1] (Jordan). "Posidonomya" is stated to lie very thickly on the faces of the shale; to be of an oblique-oval shape, 3—4 millimetres in length,[2] with 8-10-15 concentric wrinkles, which are the less numerous when they are large and strong; the hinge-border joining the hinder border with blunt but distinct angle. It is stated to be like *P. Becheri* in miniature, and to correspond in form and wrinkles to fig. 6 *a*, pl. 113, of Goldfuss's 'Petref.,' but of only half the size, and somewhat longer in proportion: the angles of the

[1] Palæontographica, vol. iv, p. 2.

[2] M. Jordan refers to some specimens 5 millem. ($2\frac{1}{4}$ lines, or $\frac{1}{5}$th inch) long; N. Jahrb. 1850, p. 578.

hinge-border, however, are said to be more distinct, and the ridges of the concentric wrinkles narrower and sharper; its length and height are as 4 : 3.

Prof. Fridolin Sandberger, of Carlsruhe, favoured me, in December, 1861, through the medium of Prof. H. G. Bronn, with some specimens of *E. tenella* from the Murgthal, Schwarzwald, labelled "From the uppermost beds of the Coal-formation, Sulzbach; Valley of the Murg. The place where it was found is now closed up." The specimens are of a black stony shale, or slate, with white streak. The *Estheriæ* are represented by black films and impressions of flattened valves lying crowded on the planes of bedding ($\frac{1}{4}$ inch apart), together with fish-scales, mica, and small decomposing crystals of pyrites.

The carapace-valves are but poorly represented, and have left no trace of their ornament in these specimens, one of which is figured, Pl. V, fig. 6.

2. A very similar form, from the Coal-measures of Lancashire, has lately been shown to me by my friend, Mr. Binney, who has so largely contributed to the series of palæozoic *Estheriæ* described in this monograph. On a small piece of fine-grained, micaceous, red, argillaceous sandstone, from Mr. Jackson's pit at Astley, Lancashire (midway between Wigan and Manchester), are several badly preserved casts of a small *Estheria* (Pl. V, fig. 5), associated with numerous casts of a *Beyrichia* (Pl. V, figs. 16, 17). "It is from the Upper Coal-measures, and was met with about 50 yards above the Four-foot Coal of Worsley, Pendleton, &c."

This little *Estheria* is apparently identical with that from the Murgthal.

3. A somewhat larger, but very similar *Estheria*, has been noticed by Mr. Salter lately in the shales of the Four-foot Coal of Bradford, near Manchester. Pl. V, fig. 1, represents one of the impressions from the shale; where they are not numerous, and are associated with *Anthracomya* (?) and *Cypridæ* (Pl. V, figs. 13, 14).

4. In the ironstone associated with the same coal there are similar *Estheriæ*, but still larger (Pl. V, figs. 2—4), which were also brought under my notice by my friend Mr. Salter. These are casts, but they retain faint traces of sculpturing (fig. 5), which appears to me to have been a reticulation, modified by pressure and crumpling, by which the interspaces have been thrown into short puckers parallel with the ridges.

The Four-foot Coal of Bradford, near Manchester, is regarded by Mr. Binney and other geologists, as being most probably equivalent to the Four-foot Coal of Pendleton and Worsley, and the Ellam's Coal near Ringley.[1] The Four-foot Coal is found at 115 yards from the pit's mouth at Agecroft Colliery; and the fire-clay above, and the clay-floor of the coal are full of *Stigmaria ficoides* (ibid., p. 161). The Four-foot Coal of Bradford, here referred to, is on the horizon of the Upper Coal-measures of Ardwick, near Manchester, and and is therefore near the top of the Upper Coal-measures.

[1] Binney, 'Transact. Geol. Soc. Manchester,' 1841, vol. i, pp. 70, 73, and 158. As the Manchester coal-field is cut off by strong faults from the neighbouring coal-fields, there is some uncertainty in the exact correlation of these seams of coal. Still, there is no doubt that they belong to the same upper portion of the Coal-measures. (See 'Map Geol. Survey,' Sheets 80 & 89.)

5. Intermediate in size between those of the ironstone and those of the shale of the Four-feet Coal, above mentioned, and better preserved, are some specimens of a similar *Estheria*, found by Mr. Grossart, of Salsburg, near Holytown, Lanarkshire, in the Coal-measures of Lanarkshire, Scotland. These are represented by shiny black impressions, readily affording traces of a delicately sculptured reticulate ornament (Pl. II, fig. 39, and Pl. V, fig. 7).

Mr. Grossart's specimens show the concentric ridges distinctly, twelve and upwards (Pl. II, fig. 39); as usual in adult *Estheriæ*, the ridges are crowded towards the ventral border. The interspaces bear a faint dotting, attributable to a delicate and minute reticulation (Pl. V, fig. 7); and in this they resemble those of *E. tenella* of Saxony (Pl. I, figs. 26, 27), to which also the *Estheria* under notice has a close resemblance in general form, except that it is not quite so oblong.

Of *E. tenella* from Lanarkshire, I have seen about a dozen individuals in a black shale. The specimens were discovered, and kindly submitted to my examination, by Mr. Grossart, who has also shown me several other *Entomostraca*, which he has discovered in the Coal-measures of that district.

In the 'Geologist,' vol. ii, 1859, p. 466, Mr. Davidson gives a tabular view of the Carboniferous Strata of the Clydesdale Coal-field (Lanarkshire). These are divisible into four great groups: 1. The Upper Coal-measures; 2. The Upper Limestone series; 3. The Lower Coal-measures; and 4. The Lower Limestone series. The Upper Coal-measures of Lanarkshire, in one band of which *Estheriæ* have been found by Mr. Grossart, is said to have, in some places, a thickness of about 159 fathoms. It contains eleven seams of workable coal, and numerous smaller seams; the "Ell Coal" one of the best known, is situated towards the top of the series. Besides the coals, this series consists of sandstones, for the most part white, or white with dark streaks, of fire-clays and shales, a bed of so-called freshwater limestone, and a few important bands of ironstone.

Mr. Grossart has sent me a list of the more important beds of this Upper Coal-measure series. The "Ell Coal" is taken as a recognisable horizon, and the distances above and below that coal are indicated in the table for the chief coals, shales, and ironstone. I have inserted the names of the *Entomostraca* with their respective beds. Most of the *Cypridæ* appear to be closely allied to *Cytheropsis* (?) *Scoto-Burdigalensis* or *C. suberecta;* but I have not yet been able to determine exactly the species, of which there appear to be about four or five.

Coal-measures of Lanarkshire.

Fathoms.	Upper Coal-measures.	
22	Palace-craig ironstone (Black band).	*Anthracosia acuta, Avicula,* and *Cytheropsis Scotoburdigalensis* (?).
16	Estheria-shale	*Anthracosia, Avicula, Spirorbis, Estheria.*
15	Upper coal.	
0	Ell coal	*Gyracanthus formosus,* here and below.
12	Main coal.	

Fathoms.	Upper Coal-measures.	
26	Splint coal.	*Anthracoptera quadrata*, here and below.
34	Coal.	
41	Ardrie black-band ironstone.	*Cytheropsis Scotoburdigalensis* (?).
55	Virtue-well coal.	
61	Bell-side ironstone[1] (Black-band).	
72	Mussel-band ironstone (in the following association of beds):	

Bituminous shale, with shells, *Cypridæ*, and fish	20	inches.
Ironstone (dark), with *Beyrichia arcuata*	2	„
Bituminous-shale	5	„
Parrot-coal	4	„
Bituminous shale, with *Anthracosia acuta*	10	„
Mussel-band, made up of *Anthracosiæ*	3	„
Bituminous shale, with shells	2	„
Ironstone, full of *Cytheropsis Scotoburdigalensis*	3	„
Dark shale	9	„
Coal	8	„

78	Coal (sometimes ironstone).	
86	Shott's furnace-coal.	*Beyrichia arcuata.*
92	Shott's smithy-coal.	
100	Shott's low-coal.	
105	Shott's gas-coal.	*Cytheropsis Scotoburdigalensis* (?), and another, *Modiola*, and *Beyrichia arcuata.*
109	Black fossiliferous shale.	
113	Coal.	
121	Coal.	
124	Coal.	
134	Coal.	
144	Slaty ironstone (Black-band).	*Lingula, Discina, Conularia*, &c., together with Fish-remains, and *Anthrapalæmon Grossarti.*

(The distance and thickness of the beds vary considerably in different localities.)

Anthracosia acuta occurs in most of the beds below the Ell-coal; *Diplodus gibbosus*, *Megalichthys Hibberti*, *Holoptychius minor*, &c., are found in nearly all the beds of the Upper Coal-formation, but more abundantly below the Ell-coal. *Spirorbis carbonarius* occurs in most of the beds up to the Splint-coal.

In the "Upper Limestone series," an ironstone, at 200 fathoms below the Ell-coal (a few feet above the highest limestone), has yielded to Mr. Grossart a new *Beyrichia* (*B. fastigiata*, sp. nov.). At 343 fathoms below the Ell-coal, in the "Lower Limestone series," Dr. Rankine, of Carluke, gets *Beyrichia multiloba* (sp. nov.); and at about 350 fathoms, Mr. Grossart has found some small Cypridina-like Entomostraca, similar to the *Daphnoidia Hibberti* and *D. primæva.*

[1] Dr. Rankine, of Carluke, has sent me specimens from about this horizon, in the Clydesdale Basin, one of which has *Cytheres* and *Spirorbis*, and another *Beyrichia arcuata* and *Anthracomya* (?).

A similar fossil has been obtained at Gare, by Dr. Rankine, at 239 fathoms; and Dr. Rankine has also sent me specimens of a bed of *Cytheropsis Scotoburdigalensis*, associated with ironstone, from 356 fathoms below the Ell-coal.

6. Barely, if at all, distinguishable from the *Estheria* communicated by Mr. Grossart, is an *Estheria* occurring in great numbers in the Brandschiefer of Oschatz, Saxony, referred to the Permian Formation by Naumann and Geinitz, to whom I am indebted for specimens, one of which is figured Pl. I, figs. 26, 27.

Under the same name, therefore, I propose to describe the specimens of *Estheriæ* communicated to me by my friend, Dr. Geinitz, of Dresden, which he refers to the species described by Bronn as *Posidonomya tenella* of Jordan. Dr. Geinitz's species came from the Brandschiefer (bituminous shale) of Salhausen; Jordan's *P. tenella* occurs in black shales in the Murgthal, near Sulzbach (see page 31) and also, it is said, in the bituminous shales of Autun, in France. I have not seen specimens from the locality last named.

The Saxon specimens are numerous, but delicate and obscure; and I owe to Mr. George West's patient and accurate labour with the microscope, the distinct and characteristic delineations of this species (figs. 26 and 27), as well as of others nearly as obscure, and of the many other better preserved *Estheriæ* described in this monograph. The specimens were supplied by Prof. Naumann, and transmitted to me by Prof. H. B. Geinitz, in July, 1859, in most ready and obliging accordance with a request from me to be made acquainted with the Permian Entomostraca mentioned in the 'Steinkohlenformation in Sachsen,' p. 4.

These *Estheriæ* lie massed together in large numbers on the planes of bedding in a dark-coloured combustible shale, belonging to the Lower Permian formation of Saxony. The shale belongs to the coal-deposit known as the "Brandschiefer" of the Rothliegendes, at Salhausen, near Oschatz, Saxony; and, besides the *Estheria*, it contains remains of *Acanthodes gracilis*, Beyrich, *Xenacanthus Decheni*, Beyrich, *Walchia piniformis*, Schlotheim, *Odontopteris Naumanni*, Gutbier, &c.[1]

The following is a more detailed account of this interesting deposit of fossil fuel,—from Geinitz's 'Steinkohlenformation in Sachsen,'[2] 1856, p. 4.

"In the lower division of the Rothliegendes, a formation altogether distinct from the Coal-measures, and comprised with the Zechstein-group, in Murchison's Permian Formation, there is found at some places in Saxony a stratum which is sometimes a pure 'Brandschiefer,' sometimes an impure black coal, and which is much used for fuel. Von Gutbier, in his 'Versteinerungen des Rothliegenden in Sachsen,' 1849, pointed out that the Plant-remains found in this bed are specifically different from those of the Coal-measures.

"The Brandschiefer appears most developed near Salhausen, between Oschatz and Mügeln, where,

[1] Professor H. B. Geinitz has obliged me with this information, in a letter dated January 22, 1861.

[2] An abstract of the chief points of this valuable work are given in General Portlock's 'Anniversary Address to the Geological Society of London,' 1857; and Dr. Geinitz's previous work on the Coal-beds of Hainich, Ebersdorf, and Floha, is noticed in Mr. Hamilton's address, 1855.

according to Naumann, it comprises six or seven beds, of which the greatest is eighteen feet thick. Naumann has described this carbonaceous shale in the first volume of his 'Lehrbuch der Geognosie,' (1849, p. 701), thus—'It varies in colour from blackish-brown to pitch-black; it is thinly and evenly laminated, therefore often splitting into very thin flakes and plates, glistening on the split faces, with greasy shining streak, easily shivering, somewhat soft, and so richly impregnated with bitumen that it burns in the fire with a more or less brisk, but very smoky, flame, without, however, falling to ashes.'

"Of Plant-remains in the Brandschiefer, the most abundant are *Lycopodites piniformis*, Schlot., and *Walchia filiciformis*, Schlot. Remains of Fish also occur—of the genera *Amblypterus*, *Holocanthodes*, *Xenacanthus*, and *Cephalaspis*: also there are the thin shells of a *Cypris*, very similar to the *Posidonomya minuta*.

"On these shells, which Bronn[1] has also found in a very similar black shale of the Murgthal, in great quantities, and which also abound in the bituminous fish-shales of Muse, near Autun (Saône-et-Loire), and Bruxière-la-Grue (Allier), in France, a lengthy discussion has been carried on by Delahaye and Landriot, as to whether they belong to the Molluscan genus *Posidonomya*, or to the Crustacean genus *Cypris*.[2]

"Without inquiring which is right in this question, we may remark that the contemporaneous occurrence of these beds at the localities mentioned, and especially their stratigraphical relations, prove their identity with those of Salhausen, which moreover must be paralleled with those occurring in the Roth-liegendes, between Trautenau and Hohenelbe,[3] in Bohemia, and those near Oslawan, in Moravia."[4]

In the 'Bullet. Soc. Géol. France' (1848), 2e sér., vol. v, p. 301, Prof. Naumann mentioned the occurrence of this bituminous schist at Oschatz, and its little bivalved Crustacean,—the latter under the name of "Cypris," which had been also applied to it (according to M. Landriot[5]) by A. D'Orbigny, in 1845. Michelin had referred these shells to *Posidonia*, with some doubt, in 1836 (see 'Bullet. Soc. Géol. France,' 1836, vol. vii, p. 321; 2e sér., vol. v, p. 305; and 1850, vol. vii, p. 33).

The specimens from Saxony, in my possession, have features very similar to those above described, and present the characteristics of *Estheria*, especially the delicate concentric ridges, separated by flattened interspaces sculptured with a reticulate pattern. This is faint (Pl. I, fig. 27), and seems to be associated with a fine dotting. Taking one of the best of the specimens as a type (and they are all so much crushed, that it is difficult to find one with a trustworthy outline), this species seems to present an obliquely sub-quadrate valve, with the corners rounded off; nearly equilateral, but rather less fully rounded in front than behind. The umbo is situated in the anterior third of the hinge-line, which is straight, long (about two thirds the length of the valve), and defined by blunt angles on either end, at the downward curving of the front and hind borders respectively.

[1] Leonhard und Bronn's 'Jahrb. f. Min.,' 1850, p. 577; where they are referred to as *Posidonomya tenella*, Jordan.

[2] 'Bullet. Soc. Géol. France,' 2e sér., 1848, vol. v, p. 304; 1849, vol. vi, pp. 90, 374; 1850, vol. vii, p. 33.

[3] Girard, in Leonhard und Bronn's 'Jahrb.,' 1843, p. 757. Beyrich, 'Bericht. K. Preuss. Akad. Wiss.,' 1845, p. 25.

[4] Von Hauer, 'Sitzungsbericht. K. K. Akad. Wiss.' Wien, 1850, p. 160.

[5] 'Bullet. Soc. Géol. France,' 2e sér., 1849, vol. vi, p. 90.

7. Lastly, I have to draw attention to a very small Permian *Estheria* from Russia (Pl. I, figs. 23, 24), having some characters very similar to those above mentioned, and which may possibly be ultimately found to be of the same species. As I do not, however, feel satisfied that I have fully elucidated this *Estheria* (*E. exigua*), I prefer to keep it separate (see below). For specimens of this *Estheria*, I am indebted to M. E. D'Eichwald.

Estheria tenella may thus be said to occur—

In Russia (*E. exigua.*). Permian.
At Oschatz, Saxony. Permian (Rothliegende).
,, Autun, France. Permian (?) or Upper Carboniferous.
,, Salbach, Black Forest. Upper Carboniferous.
In Lancashire, England. Upper Carboniferous.
,, Lanarkshire, Scotland. Upper Carboniferous.

Habitat of E. tenella.—The *Beyrichiæ* at Astley (Lancashire), *Anthracomyæ* at Bradford (Lancashire), and *Anthracosia*, *Avicula*, and *Spirorbis*, in Lanarkshire, seem to point to at least a brackish water for *E. tenella*.

4. Estheria exigua, *Eichwald*, sp. Pl. I, figs. 22—24.

Posidonomya minuta (*Bronn.*), *Kutorga.* Verhand. Min. Gesell. St. Petersb., 1844, p. 63, &c., pl. 1, figs. 1—5.
— exigua, *D'Eichwald.* Geogn. Russl., 1846, p. 456; Leth. Rossica, 1855, livr. iv, p. 231; Bullet. Soc. Imp. Nat. Mosc., 1856, xxix, 2, p. 559; Leth. Ross., 1859, livr. vi, p. 941, pl. 40, fig. 4.
Cyclas Eos, *D'Eichwald.* Geogn. v. Russlands, 1846, p. 466.
Cytherina (Cyclas) Eos, *D'Eichwald.* Bullet. Soc. Imp. Nat. Moscou, xxx, part 2, 1857, p. 307.
Posidonomya Eos, *D'Eichwald.* Lethæa Rossica, 1859, livr. vi, p. 942, pl. 37, fig. 13.
[? Estheria tenella, *Jordan*, sp. See page 31.]

The figured specimen { Height of valve, $\frac{1}{48}$ inch / Length, ... $\frac{1\frac{1}{2}}{48}$,, } Proportion 9 to 13, or 1 : $1\frac{1}{2}$—

The material at my command for the elucidation of this species is but limited. For what I have, I am indebted to the kindness of M. E. D'Eichwald, of St. Petersburg, who has courteously replied to my inquiries, and communicated specimens and information, both in the case of this and of other species of fossil *Estheriæ*. In January, 1861, M. D'Eichwald kindly favoured me with some specimens of light-grey marl, or calcareous shale, bearing remains both of *Estheria exigua* and *E. Eos*. The former is represented only by crumpled portions of the carapace. Of the latter, there are several minute individuals. Of these, which are delicate valves, beautifully iridescent under the micro-

scope, one has been carefully figured in Pl. I, figs. 22—24. It is very small, only $\frac{1}{83}$ inch in length; but, with great care, it can be made to show the ornament that is highly magnified in fig. 24. I believe that these minute *Estheriæ* are of the same species as the larger one on the same piece of marl; and that, therefore, two names are not required for them. The larger form is also very delicate, but it is thicker, and of a darker colour than the little specimens marked "*Posidonomya Eos*" by M. D'Eichwald; and the large specimen does not yield good microscopical evidence of ornament. Judging, however, by the probable collocation of large and small specimens of the same species, and by the absence of any important distinction (the relatively great size of the wrinkles being due to modification of a large specimen by pressure), I must regard both *P. exigua* and *P. Eos* as belonging to one and the same species of *Estheria*.

In communicating to me the above-mentioned specimens, M. D'Eichwald pointed out that, in his opinion, *Estheria Eos* has very fine and very numerous concentric ridges, and that "*Posidonomya*" *exigua* has strong ribs and broad furrows between them; and, though the former may probably be Crustacean, yet the latter at least, he still thinks, is really Molluscan. M. D'Eichwald also remarked, in his letter of January 19th, 1861, that the fig. 4, pl. 40, of his 'Lethæa Rossica,' represents the ridges as too small; they ought to be stronger and wider apart than in the figure there given.

The specimens sent by M. D'Eichwald are small pieces of—1. Light-grey soft marl, with "*Bairdia*[1] *Pyrrhæ*" and filmy valves of *E. Eos*, iridescent under the microscope. 2 and 3. Dark-grey hardish marl, having the surface-plane covered with delicate crumpled Estherian valves, minute and iridescent, chiefly *E. Eos;* a fragment of *E. exigua* occurs, lying with the others, on No. 2.

The little *Estheria* (figs. 22—24) from the Permian marls of Russia, has oblong valves, with the ends rounded (fig. 23, magn. 20 diam.); the posterior extremity rather more convex than the anterior; the ventral margin slightly curved; the dorsal line straight and long (equal to rather more than half the length of the valve), terminating anteriorly a little in advance of the umbo, which is forward and does not affect the outline of the valve. Concentric ridges about 15, delicate and distinct; the interspaces are neatly punctate with a minute reticular pattern (fig. 24, magn. 100 diam.).

It is difficult at first sight to find any exact correspondence between the above description of our little valves, and the description given in the 'Bullet. Moscou' and 'Lethæa Rossica,' of *Posidonomya Eos* and *P. exigua;* nor do our figures agree any better with the figures given by Kutorga and D'Eichwald. Taking in consideration, however, the difference of size of the individuals treated of here and in the works referred to, and the facts, that the coarse ridges and furrows of wrinkled individuals have been described as if they were of the same value as the delicate ridges and their neat interspaces,—that unless drawn with the *camera lucida* and a good microscope, the niceties of outline and ornament

[1] This is termed "Bairdia" by M. Eichwald; but I see no reason for referring it to that sub-genus. More probably, it is a *Cytheropsis*. (See further on, Appendix.)

are unattainable, I venture to disregard any apparent differences in figures and descriptions, and to look upon our figured specimen as a young form of *Estheria exigua*, Eichwald, sp. And I am confirmed in this view by receiving specimens of *E. exigua* and *E. Eos* associated on one piece of marl, as above stated.

The history of the species is as follows:—

A small Estherian fossil, from Kargala, near Orenburg, was described (under Bronn's name, *Posidonomya minuta*) by S. Kutorga, in 1844 (Zweiter Beitrag zur Palæontologie Russlands, in the 'Verhandl. d. R.-K. Mineral. Gesellsch. St. Petersburg,' Jahr 1844, pp. 63, 66, 86, pl. i, figs. 1—5), as occurring in a hard, ash- and black-grey shale (the laminæ sometimes $\frac{1}{2}$ inch thick, sometimes very thin, and the planes of bedding streaked with copper-green), referred by Von Qualen to the lower group of the Zechstein-formation of the Government of Orenburg. Kutorga carefully indicates at p. 86, what appears to him to be points of difference between the Russian and the German (Bronn's) specimens. Remains of plants abound in this copper-shale; they were termed *Voltzia brevifolia* (Brongn.) by Kutorga, but D'Eichwald has subsequently referred them to *Ullmannia Bronnii*, Goepp., *U. Biarmica*, Eichw., and *Walchia lycopodioides*, Brongn.

In 1855 ('Lethæa Rossica,' livr., 4, p. 231), D'Eichwald described his *Posidonomya exigua*[1] as occurring in this cupriferous marl-shale of the neighbourhood of Kargala, in the district of Bjelebei, government of Orenburg. This little fossil he found associated with *Ullmannia*; and he regarded it as being probably a freshwater Mollusc. In the 'Bullet. Soc. Imp. Nat. de Moscou,' année 1856, vol. xxix, seconde partie, p. 559, M. D'Eichwald described *P. exigua*, as being very small, ovate, with the hinge-border lengthened backwards, the surface transversely wrinkled, with not more than eleven very fine punctured wrinkles. In 1859 ('Leth. Ross.,' livr. 6), after noticing the occurrence of a shell referred by him to "*Posidonomya minuta*, Goldf.," in shale of apparently Carboniferous age, near Izoume (Isjoum, 'Bullet. Moscou,' 1856, xxix, 2, p. 559), in the Government of Kharkoff (p. 940), and after remarking that most palæontologists still consider this little fossil to be a Mollusc, M. D'Eichwald described his *P. exigua* (p. 941, pl. 40, figs. 4 *a*, and 4 *b*), referring to Kutorga's previous account of it (see above), but suggesting that Kutorga's figure (fig. 5) of "*P. minuta* enlarged" may perhaps be a young *Unio umbonatus*. The following is D'Eichwald's description of *P. exigua*:

"Teste exigua, ovata, cardinali margine postrorsum prolongato, superficies sulcata transversis sulcis concentricis, 6 vel 11 nec pluribus, tenuiter punctatis:—In the copper-bearing sandstone of Kargala, Gov. Orenburg, associated with *Ullmannia Bronnii*.

"The little specimen figured (pl. 40, fig. 4 *a*, grand. nat. *b*, grossi) has the hinge-border straight, and the umbo scarcely projecting at the middle of the border, which, bent in a little arc, and obtuse at the two sides, is ordinarily prolonged equally before and behind; the furrows form little concentric striæ to the number of 6—11, very fine and

[1] Previously described in the Russian language in the 'Geogn. Russie,' 1846, p. 456.

sharp. The number of the concentric furrows is very variable; when there are only 6, they are deep, large, and removed one from another; when the number is double, they are straight and placed near together; it is then that the hinge-border becomes long and straight.

"The shell is so thin and delicate, that it bears many irregular depressions over all its surface. It is a little broader than long; the diameter is from 1 to 2 lines."

Kutorga observes (*loc. cit.*) that, in his specimens, there are 10—13 sharp, outstanding, concentric wrinkles; that the shell is very thin, and therefore seldom perfect, but occurring mostly as impressions.

M. D'Eichwald also figured and described in the same work (p. 942, pl. 37, fig. 13 *a*, 13 *b*), his *Posidonomya Eos*, previously termed by him *Cyclas Eos*, in the 'Geogn. de Russie,'[1] 1846, p. 466; and 'Bullet. Mosc.' 1856, xxix, 2, p. 575; and *Cytherina Eos*, 'Bullet Mosc.,' 1857, xxx, 2, p. 307. *C. Eos* is described as a very thin and friable little fossil, occurring in brownish-grey shale near Burakova, in the Government of Kazan; half a line broad, and a fourth of a line long, equally rounded on both margins, and marked with a little notch in front of the somewhat projecting umbo. In the 'Lethæa Ross.,' *Pos. Eos* is said to measure $1\frac{1}{2}$ line in one diameter, and nearly as much in the other, and is thus described.

"Testa minima, oblique ovata, vertice vix prominulo margini antico approximato, cardinali margine subalato, postice obtuso, superficies tenuiter transversim striata."

It seems to me quite possible that better materials might bear evidence of *E. exigua*, *E. Eos*, and *E. tenella*, (page 31) being all of one and the same species.

The nature of the habitat of *E. exigua* is obscure. *Cytheropsis Pyrrhæ* (see Appendix) may have been marine (according to what is known of its congeners), or otherwise.

5. Estheria Portlockii, *Jones*. Plate I, fig. 25.

Posidonia minuta, *Portlock*. Report Geology Londonderry, &c., 1843, p. 469.

Height of valve, $\frac{2\frac{1}{2}}{1\frac{1}{2}}$ inch
Length nearly... $\frac{3\frac{1}{2}}{1\frac{1}{2}}$ „ } Proportion 27 to 40, or 1 : $1\frac{1}{2}$—

It is with some doubt that I refer this unique fossil (a somewhat worn and imperfect concave impression) to *Estheria*. For certain it does not belong to *Estheria minuta*, which will be presently described. Still, it may be the cast of an *Estheria*, with which genus its outline and disposition of concentric wrinkles appear to be consonant. It is relatively large, but *E. striata* and others are larger. Its wrinkles are broad, but not too broad for an *Estheria* (see Pl. II, fig. 16).

This species (which I have named after its discoverer, one of the most eminent of the geological explorers of Ireland) appears to have been of a subovate form, narrowest behind; slightly curved on the ventral side, and straight on more than the central third of the dorsal edge; the umbo was a little in advance of the middle of the shell, the valve had

[1] Published in the Russian language.

about 12 concentric wrinkles, the interspaces being broad. (No ornament remains on the cast.) This is a unique specimen, in a matrix of fine-grained red sandstone, with micaceous bed-planes. It is in the Museum of Practical Geology, Jermyn street, and is labelled "Killyman, Co., Tyrone." It is referred to in J. E. Portlock's 'Report on the Geology of the County of Londonderry, and of parts of Tyrone and Fermanagh' (1843). In describing the locality where *Palæoniscus catopterus* (regarded by the author as belonging to the "Poikolitic" formation) was found, the following observations are made (pp. 468 and 469):

"This curious fish has been submitted to Professor Agassiz, and will very soon be published by him in the 'Fossil Fishes.'[1] It appears to have been in great abundance in one locality and in one layer of the red earthy sandstone of Rhone Hill, near Dungannon. The space occupied by the fishes was very small, being not more than a few square feet, and the specimens obtained entirely exhausted it; for, though an excavation was made of considerable extent, and carried carefully down to the level of the layer, and then below it, not a single additional specimen was discovered. Within that space they were crowded together, the surface of the layer being covered with them. The general size is 2·9″ long; but one which is more isolated is 3·75″ long and ·63″ deep. A small shell, *Posidonia minuta*, which, though not actually in the same layer, is found in the soft clayey seams which separate the adjacent layers, has been found in other localities [not in Ireland], but without any trace of the *Palæoniscus*. The only known localities [for this fish] is therefore Tyrone, Rhone Hill."

Other information respecting these red sandstones was given some years previously in a paper, by Sir R. I. Murchison, "On the Recent Discovery of Fossil Fishes (*Palæoniscus catopterus*, Agassiz) in the New Red Sandstone of Tyrone, Ireland," published in the 'Proceedings of the Geological Society,' vol. ii, p. 206, 1835.[2] It is here stated that—

"The quarry is at Rhone Hill, in the parish of Killyman, about three miles east of Dungannon. The New Red Sandstone in which it is excavated is a prolongation of the deposit which occupies large tracts in the county of Antrim, and extends into this part of Tyrone, where it surrounds a small, slightly productive coal-field, but reposes for the greater part upon Mountain-limestone....The beds of New Red Sandstone exposed in the quarry dip about 15° to the N.N.E., and consist, in the upper part, of red and green marls, passing down into a dark-red, thickly bedded, siliceous sandstone, with a few irregular, highly micaceous way-boards, of a deep-purple colour. The surface of some of the beds exhibits ripple-marks. The quarry (which is the property of Mr. Greer) is from 25 to 30 feet deep, and the fishes are found only in the bottom-beds, but are in great abundance."

[1] Ultimately described by Sir P. Egerton, in the 'Quarterly Journ. Geol. Soc.,' vol. vi, p. 4; and vol. xiv, p. 165, pl. 11, fig. 4.

[2] Also referred to in the 'Silurian System,' 1839, p. 43.

In both of the foregoing extracts this red sandstone is treated of as Triassic in age;[1] but of late years it has been referred to the Permian formation, as shown by the *Pal. catopterus* being termed "Permian" by Sir P. Egerton in the 'Quart. Jour. Geol. Soc.,' vol. vi, p. 9, and by Mr. Morris in his 'Catalogue of British Fossils,' 2nd edit., 1854, p. 336. Its geological place has not yet been determined by the geological surveyors, and for the present I prefer to regard it as of Permian age.

The stratigraphical position of the red marl and sandstone of Rhone Hill (Tyrone) is noticed at p. 481 of Portlock's 'Report Geol. Londonderry,' &c. The red marl is regarded as the same as that underlying the Chalk and Greensand at Benbradagh (Londonderry), and having a thickness there of between 600 and 700 feet, and overlying marls and sandstones, not less than 1000 feet thick, to which succeed the Carboniferous and Devonian strata.

6. Estheria minuta, *Alberti*, sp. Pl. I, figs. 28—30; Pl. II, figs. 1—7; Pl. V, figs. 8, 9.

Posidonia minuta, *Alberti*. *Von Dechen's* De la Beche's Handbuch der Geologie, 1832, p. 453.
— Goldfussii, *Alberti* (?). Ibid.
— Keuperiana [vel Keuperina], *Voltz*. Ibid.
— minuta (*Goldfuss*), *Alberti*. Jahrbuch f. Min., 1832, p. 227.
— — (*Alberti*), *Zieten*. Die Versteinerungen Württembergs, 1833, p. 72, pl. 54, fig. 5.
— — (*Goldfuss*), *Alberti*. Monographie, &c., 1834, pp. 114, 120, 121, 202.
— — *Goldfuss*. Petrefact. Germaniæ, pars ii, 1834-40, p. 118, pl. 113, fig. 5.
— — *Voltz*. Mém. Mus. Nat. Hist. Strasbourg, 1837, vol. ii, p. 7.
— Albertii, *Voltz*. Ibid.
Posidonomya minuta, *Bronn*. Leth. Geogn. (1835-38), vol. i, p. 164, pl. 11, fig. 22.
— — *Strickland* and *Murchison*. Transact. Geol. Soc., 1840, 2d ser., vol. v, p. 337, pl. 28, fig 4.
— — *Bronn*. Leth. Geogn., 3rd edit. (1851), vol. ii, part 3, p. 60, pl. 11, fig. 22.
Estheria minuta, *Rupert Jones*. Quart. Journ. Geol. Soc., vol. xii, p. 376.

From Sinsheim.....	Height of valve... $1\frac{1}{12}$ inch	Proportion 16 to 21, or 1 : $1\frac{1}{3}$—	
	Length ..... $1\frac{3}{12}$ „		
„ „	Height ..... $1\frac{1}{12}$ „	Proportion 18 to 27, or 1 : $1\frac{1}{2}$.	
	Length ..... $2\frac{1}{12}$ „		
„ „	Height, more than $\frac{1}{9}$ „	Proportion 1 to $1\frac{1}{2}$.	
	Length ..... $\frac{1}{6}$ „		
From Sulzbad, var. *Albertii*.....	Height, less than $\frac{1}{10}$ „	Proportion 7 to 12, or 1 : $1\frac{3}{4}$—	
	Length ..... $\frac{1}{6}$ „		

[1] We must remember, however, that each of the terms "New Red Sandstone" and "Poikolitic" comprised, until about 1841, both the "Upper Red Sandstone" and the "Lower Red Sandstone," the latter of which was then divided off, with the magnesian limestone, under Murchison's term "Permian."

Carapace convex, compressed-oviform, like a *Pisidium*.[1] Carapace-valves more or less oblong, with rounded corners, or subovate; varying in outline from subquadrate (Pl. I, fig. 28) to irregular ovate (Pl. II, fig. 1). The hinge-border is straight, but varies somewhat in relative length, sometimes falling away quickly into the curve of the posterior border (as in Pl. II, fig. 4), sometimes equal to two thirds the length of the valve; the umbo is placed forwards, at the end of the hinge-border, and the anterior margin curves away in front of it, with a bold, semicircular outline. The ventral border is more or less convex, usually symmetrical, but sometimes oblique (Pl. II, figs. 1 and 5), trending upwards posteriorly; the hinder margin is rounded, like the anterior, but it is longer, more contracted, and less obtuse, giving an obliquely ovate outline to the valve, which is highest anteriorly, whilst in *E. striata*, *E. Mangaliensis*, and *E. Murchisoniæ*, it is highest posteriorly. Figs. 2 and 6, Pl. II, show the lateral convexity of the carapace to be greatest just behind and below the umbo, in the anterior third of the shell. Between the concentric ridges (which are about 14 in number and upwards), the carapace bears a reticulate ornament[2] of irregularly hexagonal meshes, 5 to 7 of which may be traced from ridge to ridge; the size of the meshes and the thickness of their walls varying very much in different specimens (Pl. I, fig. 30, and Pl. II, figs. 3 and 7), according to the degree of fossilization and wear, for the most part.

The best specimens which have afforded me exact information as to the form, structure, and features of the carapace of *Estheria minuta* are from Pendock, Worcestershire (Pl. II, figs. 1—3); all others that I have seen have suffered so much from pressure and from loss or modification of the shell-substance that the evidence they afford of the original conditions of the carapace is very obscure. A variety of *E. minuta* occurs also in the beds between the Trias and the Lias (Rhætic) of England and Scotland; and carapaces of this variety occur in excellent preservation in some localities (Pl. II, figs. 9—15).

To understand rightly the exact relationship of the Triassic and Rhætic *Estheriæ* of Britain to *Estheria minuta* of the Trias of the Continent, we must first take the latter in hand, and work out its characters, geological position, and bibliography.

The chief specimens of the German *Estheria minuta* that I have examined have come from the south-western portion of the Triassic area of Baden, Würtemberg, and Bavaria, through the kindness of F. von Alberti, Sandberger, Bronn, Krantz, Hassencamp, and others. From the Thuringian and Hanoverian Triassic areas, in some parts of which *E. minuta* has been described as occurring abundantly, I have only one (Thuringian) specimen. Of French specimens, from the Trias of the Vosges (Alsace), I have some from Soultz-les-Bains, communicated by Dr. Schimper.

My German specimens are—

[1] Resembling in general appearance several of the recent *Estheriæ*,—such as those figured in pl. 11 (*Annulosa*) of the 'Proc. Zool. Soc.,' 1849.

[2] Very similar to that of the recent *E. Dahalacensis*, Durckh., from the freshwater marshes of the Island of Dahalac, Abyssinia. (Baird, 'Proc. Zool. Soc.,' 1849, p. 89, *Annulosa*, pl. 17, fig. 2.)

1. From the Muschelkalk (or rather the Lettenkohle-group) on the Prim, near *Rothenmünster*, not far from *Rottweil*, about 50 miles south of Stuttgart. A dark-grey, hard, argillaceous, thin-bedded rock, very slightly calcareous, weathering ochreous; casts of *Estheria minuta* (varying from $\frac{2}{12}$ inch to $\frac{1}{12}$ and less in length) on the plane of bedding. From Mr. F. von Alberti, of Friedrichshall.

2. From *Haigerloch*, in Swabia (Hohenzollern), 32 miles S.S.W. of Stuttgart, and 44 miles S.E. of Strasburg. Light-brown and fine-grained limestone (weathering grey), from the dolomitic beds of the Lettenkohle formation, between the Muschelkalk and the Keuper. The specimens (casts of apparently double valves) are in the mass of the specimen, and are but few. From Dr. Krantz, of Bonn.

3. From *Sinsheim*, in Baden, on the Elsenz, 23 miles S.S.E. of Mannheim. Brown, fine-grained, gingerbread-looking, dolomitic (?) limestone. The *Estheriæ* (casts of double valves) lying crowded on two planes of bedding, which are half an inch apart. Fragments of *Myalina* (?) accompany the *Estheriæ* on one of the specimens. These are marked "Keuper-Mergel," and were given to me by Dr. Krantz.

4. From Heilbronn, on the River Neckar, in Würtemberg, 36 miles north of Stuttgart. Yellowish-grey, fine-grained, argillaceous stone, hard and heavy, and finely micaceous. *Estheriæ* numerous in casts on the surface-planes, together with *Lingula tenuissima* in equally large numbers, and a cast of the two valves of a *Pleurophorus*. Belonging to the "Lowest beds of the Keuper-Mergel." Two specimens, from Sir C. Lyell.

Another specimen, very similar, but with the *Lingulæ* in better condition, and the Estheria-casts less flattened, from MM. Engelhardt and Schimper, marked "Dolomie supérieur du Muschelkalk."

These specimens afford crushed carapaces and often shell-less casts, which are wrinkled, rather than ridged, concentrically, and they rarely afford a clear trace of the distinctive reticulate sculpture (Pl. I, fig. 30).

5. Light-brown, laminated, sandy clay, with numerous delicate casts of *Estheriæ*, of different sizes,[1] on a bed-plane. From the Lettenkohlenschiefer (shales of the Lettenkohle), near Weyhers, Bavaria. This was kindly sent to me in February, 1862, by Herr E. Hassencamp, of Weyhers (Franconia), Bavaria, in fulfilment of a wish expressed, in the 'Neues Jahrbuch,' 1861, Heft 7,[2] p. 834, that I might be favoured with specimens of *Estheriæ* by Continental geologists.

Mr. Hassencamp informs me that the *Estheria minuta* occurs in the West Rhön—

(1) In the Lettenkohlenschiefer near Weyhers and Fulda, as well as in the dolomite belonging to the latter, also containing *Lingula tenuissima*.

[1] These are all small, varying from $\frac{1}{12}$ to $\frac{1}{12}$ inch and less in length.

[2] A provisional list of the species of *Estheriæ* that I had met with in November, 1861, appears in this number of the 'Neues Jahrbuch;' considerable alterations, however, in the list have since been made, as are shown in this monograph.

(2) In the uppermost beds of the Muschelkalk, with *Lingula tenuissima*, near Weyhers.

(3) In the Bunter ("Rothe"), just under the lowest bed of the Muschelkalk, on the Eube, near Gersfeld.

6. From near Halle, on the Saale (Thuringia).

Greenish-grey, micaceous shale. The *Estheriæ*, large and small,[1] occur on the bed-planes; these have preserved their shape, but retain only a dull, thin, pulverulent film of the carapace. Labelled "Uppermost Buntsandstein." From Prof. Fridolin Sandberger, of Carlsruhe.

Prof. Fr. Sandberger informs me, through Dr. H. G. Bronn (who kindly communicated to me the specimens from Prof. Sandberger and Mr. von Alberti), that he has met with this *Estheria* at Durlach, near Carlsruhe (Baden), in the Muschelkalk just above the Wellenkalk; also in the Lettenkohle of Nimburg, near Bottingen, in the Breisgau.

Estheria minuta in Baden, Würtemberg, and Bavaria.—This little fossil has been known to geologists for about thirty years as characteristic of the Upper Trias of Germany, attention having been drawn to it by F. von Alberti; and Voltz seems to have recognised it as an important fossil of the Keuper about the same time. It was referred to the molluscan genus *Posidonia* (subsequently *Posidonomya*, Bronn). Alberti and Goldfuss seem to have coincided in terming it *P. minuta*, for the former refers to the latter (in 1832,[2] and again in 1834,[3] when he described the species) as the authority for this name, although he used it before Goldfuss had published his description and figure. Von Dechen (1832) and Zieten 1833) refer to Alberti as the giver of the name, and in this I propose to follow them.

1832. In H. von Dechen's German edition of De la Beche's 'Handbook of Geology,' (H. T. de la Beche's 'Handbuch der Geologie, bearbeitet von H. von Dechen,' Berlin, 1832), p. 453, we find the earliest published specific name for this little fossil. Thus:—"*Posidonia Keuperiana*, Voltz (*P. Goldfussii*, Von Alberti?), Swabian Hall,[4] Lower Beds. ——— *minuta*, Von Alberti, Rottweil."[5]

1833. In C. H. von Zieten's 'Die Versteinerungen Württemberg's, 1830-33, we have, at page 72—

"*Posidonia minuta*, Alberti, De la Beche, bearbeitet von Dechen, Berlin, 1832, p. 453. From the copper-marl of Rottweil." This is figured in Zieten's pl. 54 fig. 5.

1834. In 1834, F. von Alberti, in his 'Beitrag zu einer Monographie des Bunten Sandsteins, Muschelkalks und Keupers, und die Verbindung dieser Gebilde zu einer

[1] Varying in length from $\frac{2\frac{1}{2}}{12}$ to $\frac{1}{16}$ inch.

[2] 'Jahrb. f. Min.,' 1832, p. 227.

[3] 'Monographie,' p. 114.

[4] In Würtemberg, on the Kocher, thirty-five miles north-east of Stuttgart. The name here attributed to Voltz does not appear to have been given in connection with any description.

[5] In Würtemberg, about fifty miles south of Stuttgart.

Formation,' published full particulars as to the occurrence of the so-called Posidonia minuta in certain beds of the Trias.

The Triassic striata of the Würtemberg district he grouped thus:

- Keuper[1] (900—1000 feet.)
  - Keuper-Sandstein, or variegated marls with sandstone. (Including the so-called bone-bed of the Lias.)
  - Keuper-Gyps, or variegated marls with gypsum. (Including a Reptiliferous breccia.)
  - Lettenkohlengruppe
    - Gypsum.
    - Limestone.
    - Dolomite (50 feet).
    - Sandstone.
    - Marl-slate (*Estheria*).
    - Lettenkohle[2] (1—12 inches).
    - Shale and sandstone (*Estheria*).
- Muschelkalk (700—1030 feet)
  - Limestone of Friedrichshall (150—400 feet).
  - Anhydrite-group (350—400 feet).
  - Wellenkalk (200—240 feet).
- Bunter Sandstein (600—800 feet).

At pp. 114, 119, and 120, of Alberti's 'Monographie,' he says—"Above the dolomite of the Muschelkalk, and below the Lettenkohle (Coal-shale), are clay-beds and shales, which pass more or less into sandy shale, and sometimes into sandstone, and then they become very micaceous. In these strata occur *Equisetum arenaceum*, Bronn, *Tæniopteris vittata*, var. *major*, Brongn., and Fucoidal bodies; also Reptilian remains (*Mastodonsaurus*), *Gyrolepis tenuistriatus*, Ag., *Hybodus sublævis*, Ag., and *Posidonia minuta*, Goldfuss.

"P. minuta, *Goldf.*, is square-oval, with 9 or 10 concentric ribs, of the size of a flax-seed; like *P. Becheri* (Bronn) from the Grauwacke, and the *P. Bronni* (Goldf.) of the Lias, but smaller and thinner. It is figured in Von Ziethen's 'Verst. Würt.,' pl. 54, fig. 5. It occurs at the Primthal,[3] near Rottweil (about fifty miles south of Stuttgart), in the Bore-hole No. 3, near Schweningen."

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[1] A detailed section of the Keuper, as seen near Stuttgart, is given in the 'Silurian System,' p. 30; and a careful comparison of the English German, and French Triassic beds will be found in the same chapter.

[2] In his 'Steinkohlenformation in Sachsen,' p. 4, Geinitz says—"The Lettenkohle (Shale-coal or Keuper-coal) is described by Voigt, in his 'Versuche einer Geschichte der Steinkohlen, der Braunkohlen und des Torfes,' as the generally impure, argillaceous, and pyritous coal-beds of the Keuper, lying on the Muschelkalk, and met with on the Schösserberg, near Mattstedt in the Grand-Duchy of Weimar, and at some other places in Thuringia, in France, in Saxony, on the bank of the Main, near Schweinfurt in Swabia, and in Lothringen. It is of little value as a fuel, even for lime-burning and furnaces, and is chiefly used for the manufacture of alum and vitriol. The organic remains of the Lettenkohle-group have been described in a monograph by J. G. Bornemann, in 1856."

[3] A specimen from the valley of the Prim is referred to above (p. 44), as having been kindly presented to me of late by the veteran geologist Von Alberti.

At pp. 113 and 114, we have the following section of the beds in which P. MINUTA occurs, in descending order:

	Feet.
Dolomitic rocks of the gypsum-group.	
Greenish-grey marl-slate	1
Yellowish-grey, dolomitic, marly beds, with some impressions of Plants, *Lingula tenuissima*, and *Posidonia minuta*	$2\frac{3}{4}$
Grey dolomite	$\frac{1}{2}$
Dolomite, with indistinct Shell-remains	1
Aluminous sandy shale, with indistinct Plant-remains, carbonaceous patches, and much mica. Equivalent to the sandstone of the Lettenkohle-group	$4\frac{3}{4}$
Dolomite	$\frac{3}{4}$
Dark, ash-grey, somewhat sandy shale, with calcareous and sandy nodules	1
Grey dolomite	1
Blackish-brown, sandy, and micaceous marl-slate, full of carbonaceous patches, and with remains of Fishes and Reptiles. Equivalent to the Lettenkohle	$5\frac{1}{2}$
Ochre-yellow, dolomitic marl	$3\frac{3}{4}$
Ash-grey, shaly clay, with fragmentary shells	$7\frac{1}{2}$
Yellowish-grey dolomite.	

This section was taken from the shaft above the Bore-hole No. 3, near Rottenmünster, and from the neighbouring bank of the Prim.

At pp. 116 and 117, the section of the "Posidonia-marls," near Rietheim, is given thus:—"Above Rietheim, near Hall,[1] there are on the Muschelkalk a few inches of dolomite, full of remains of Reptiles and Fishes, then the Lettenkohlensandstein.

"In the quarries between Rietheim and Bieberfeld the sandstone (Lettenkohlensandstein) is thirty to thirty-five feet thick, in beds of as much as three and a half feet thick. It contains a quantity of Reptilian and Fish remains, and fine impressions of Plants; thereon lie sandy marls, passing into shaly sandstone, and containing many Plant-impressions; light-grey in colour, passing into yellowish-grey (eight to ten feet thick); yellow and grey marl, harder downwards, and dividing itself into beds of five or six inches thick, rich in *Posidoniæ*. Above that come variegated marls. Above the Posidonia-marls appear here and there the Lettenkohle, then again yellow, and lastly variegated marls."

At p. 121, he adds:—"The Mergelschiefer [marl-shale] above the Lettenkohle is of grey, yellow, or green colour, and often passes into shale, sandstone, or dolomite. It contains Reptilian remains, Fish remains (*Acrodus* or *Hybodus*), and Plants (*Equisetum arenaceum*,[2] Bronn, *Tæniopteris vittata*, var. *major*, Brongn., *Pterophyllum longifolium*, Brongn.), also *Posidonia minuta*, *Lingula tenuissima*,[3] and a bivalve like *Sanguinolaria* in form.

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[1] In Würtemberg, thirty-five miles north east of Stuttgart.

[2] This is the *Equisetites Bronni*, Sternberg, and the *Calamites arenaceus minor*, Jaeger.

[3] According to Alberti, op. cit., p. 318, *Lingula tenuissima*, Bronn, occurs in the Dolomite, the Lettenkohlengruppe, in the Muschelkalk, and in the Bunter Sandstone. It occurs, according to Bornemann ('Org. Reste Lettenkohl.,' 1856), rarely in the Myacites-clay of the Lettenkohle-group, but more abundantly in certain of the passage-beds between that group and the Muschelkalk. Having examined several specimens of Triassic rocks containing *Lingulæ*, namely, those already mentioned (p. 44), and some others kindly lent me by M. Engelhardt, of Niederbronn, and Dr. Schimper, of Stuttgart, I have noticed

At p. 202, Von Alberti mentions the occurrence of *Posidonia minuta* in red standstone (Bunter Sandstein), together with Plant-remains, near Sulzbad (Bas-Rhin), and Corcelles (Haute Saône); also *Lingula tenuissima* at Sulzbad and Douptail. (These and other fossils, many undetermined and undeterminable, were seen by Alberti in the Museum of Strasburg, in 1831.)

At p. 320, it is stated that *Psammodus Elytra, Avicula subcostata, Posidonia minuta,* and *Equisetum arenaceum* occur both in the Bunter Sandstone[1] and in the Keuper.

1834-40. In A. Goldfuss's 'Petrefacta Germaniæ,' Zweiter Theil. (1834-40), p. 118, the following occurs:

"*Posidonia minuta,* nobis, Pl. 113, fig. 5. Posidonia testâ minutâ, transversim ovato-rotundâ, planâ, inauriculatâ, costis majoribus concentricis (8-10) minoribusque marginalibus confertis. Zieten, *l. c.,* pl. 54, fig. 5. These small shells occur bed-like in the Keuper, especially at Hassfurth[2] (not far from Schweinfurth),[3] near Heilbronn,[4] and at Pforzheim.[5] Usually there is only the impression of the outer surface, rarely the remains of the extremely thin shell. The shell is flat, obliquely roundish oval, and has 8-10 convex, regular, concentric wrinkles. In the lower third these become smaller, and lie closer together. There are no ear-like processes."

1843. In giving an account of the Triassic beds of Würtemberg, 1843 ('Das Flözgebirge Würtemberg's,'[6] p. 541, &c.), F. A. Quenstedt separates the Lettenkohle-group from the lower part of the Keuper, and ranks it as the upper member of the Muschelkalk. Hence some authors refer to *Estheria minuta* as belonging to the Keuper, after Alberti's classification; whilst others speak of it as being lower in the scale, either as occurring in the Upper Muschelkalk or between that and the Keuper, according to their views as to the relations of the Lettenkohle for this is regarded by some as being distinct from both the Upper Muschelkalk and the Keuper. Quenstedt's classification is shown in the following table:

that in the Grès Bigarré, of Sulzbad, there is a *Lingula* three fourths of an inch long, and three eighths wide; that in the hard, dark-grey shale of the Wellenkalk of Horger, Würtemberg, there is a *Lingula* half an inch long, and three eighths wide; that in the dolomitic marlstone of the Lettenkohle of Durlach, Baden, the *Lingulæ* are one fourth of an inch long; and lastly, that in the Estherian marlstone, near Heilbronn, the *Lingulæ* are only three sixteenths of an inch in length. This gradual dwarfing of the *Lingulæ* (in the ratio of six, four, two, and one a half), as we rise in the series towards the Keuper, indicates the gradually increasing influence of some agency unfavorable to the growth of these Brachiopods, such, perhaps, as a larger and larger influx of fresh water into their habitat, until the water became sufficiently free from salt to allow of the presence of *Estheriæ,* whilst the *Lingula tenuissima* still survived.

[1] *P. minuta* is not mentioned amongst the fossils of the German Bunter Sandstone, at p. 39, but it is at p. 202, as found at Sulzbad.

[2] In Bavaria, on the River Main, thirty-four miles north-east of Wurzburg.

[3] In Bavaria, on the right bank of the River Main, twenty-four miles north-north-east of Wurzburg.

[4] In Würtemberg, on the River Neckar, twenty-miles north of Stuttgart, twenty-six miles south-east of Heidelberg.

[5] In Baden, at the confluence of the Enz and the Nagold, fifteen miles south-east of Carlsruhe.

[6] Tübingen, 8vo, 1843.

- **Keuper**
  - *e.* — Yellow, hard sandstone, with Bone-bed. *Modiola minuta, Avicula gracilis,* and *Myacites.* Patches of coal. / Red clays.
  - *d.* — White sandstone, alternated with bright-coloured and blue clays; coal-patches; silex and agate. Reptilian bones.
  - *c.* — Variegated marl and sandstone, with foot-tracks and ripple-marks. Shells rare.
  - *b.* — Green and reddish sandstone. Plants.
  - *a.* — Gypsum and marls. Shells. Reptiles. *Ceratodus.*
- **Muschelkalk**
  - *d.* Lettenkohle — Dolomitic limestones. *Estheria minuta, Lingula tenuissima, Trigonia Goldfussii, Gervillia socialis.* Fishes. / Marl and clay. *Mastodontosaurus.* / Grey sandstone, with *Equisetites*
  - *c.* Muschelkalk proper — Grey sandstone, with Bone-bed. *Coprolites, Gryolepis tenui-striatus, Acrodus Gaillardoti, Psammodus, Hybodus plicatilis, Dracosaurus Bronnii.* / Dolomite, and limestone. *Pemphyx Sueurii, Fucus Hehlii.* / Thin marly limestones. Saurian and Fish-remains, *Ceratites nodosus, Encrinites liliiformis,* and abundance of marine shells. / Limestones.
  - *b.* Salt-group — Limestone. / Clays with gypsum and rock-salt. / Limestone.
  - *a.* Wellenkalk — Wellenkalk / Wellendolomit } Marine shells, &c.
- **Bunter**
  - *b.* Red sandstones.
  - *a.* Sandstone.

Quenstedt thus refers to *Estheria minuta* and *Lingula tenuissima* of the Keuper, in his 'Flözgebirge Würtembergs,' pp. 71 and 75. "Above the Lettenkohle (he says) is an extremely hard dolomite, several feet thick, lying between thin dolomitic beds, darkish in colour, and streaked with yellow. Careful search in the thin dolomites overlying the hard variegated dolomite, may be made with interest, for at every splitting of the beds the little *Posidonia minuta* scales off in thousands; and in some specimens a thin-shelled *Lingula* occurs, which in this association, although without any very striking characteristic of its own, becomes the strongest boundary-mark for the Muschelkalk formation. This fine-striped *Lingula*, called *tenuissima*, on account of the thinness of its shell, is distinguished only by its place of occurrence from the *Lingulæ* of other formations. It lies always above the sandstone and variegated dolomite (Flammendolomit), and scattered among the *Posidoniæ*. *P. minuta* is seldom many lines in diameter, it has an obliquely oval shell with a straight hinge, and is only on account of its concentric wrinkles recognised as a *Posidonia*. The specimens might be taken for badly preserved *Astartes*, or many other shells; so little is known of its generic characters."

Again, in his 'Handbuch der Petrefaktenkunde,' Tübingen, 1852, p. 516, Quenstedt says—"*Posidonomya minuta* (pl. 42, fig. 13; 'Zieten. Verst.,' pl. 54, fig. 5) lies in millions in the dolomitic beds above the Lettenkohle. This little longish shell may as well belong to an *Astarte*, or any other bivalve. From the impressions this cannot be decided."

1851. From H. G. Bronn's third edition of his 'Lethæa Geognostica,' 1851, vol. ii,

part 3, p. 60, after a list of synonyms, of which we have availed ourselves (with some slight corrections), *Posidonomya minuta* is stated to occur in the following localities.

Rarely in the Bunter Sandstone, with plants, at Sulzbad and Corcelles; also in the uppermost part of the Muschelkalk (ζ), near Biberfeld in Würtemberg; more plentiful in the Lettenkohlen-Gruppe (κ) of Würtemberg on the Schwarzwald, near Rottweil, at Rottenmünster, and elsewhere (ο, ρ, Alberti, τ Quenstedt); also at Pforzheim and at Sinsheim, near Heidelberg; in the uppermost layers of the Keuper Sandstone (εε) in Würtemberg (Täbingen); and, as it appears, still higher, increasing in size (to 7‴ long). Lastly, at Hassfurth, near Schweinfurth (Goldfuss), and in the Keuper, near Weimar; in the Upper Keuper, at Ellichausen, near Göttingen, and in the Upper Bunter Sandstone, near Dassel, in the Solling. *Posidonia Keuperina* has been recorded from the Lower Keuper beds at Hall, in Swabia, and is probably identical.

On the other hand, adds Bronn, the occurrence of the true *P. minuta* in the Russian Copper-sandstone (Kutorga, in Jahrb., 1844, p. 742, and his Zweit. Beitrag zur Paläontol. Russl., 1844, p. 14, pl. 1, fig. 4 (Comp. Jahrb., 1849, p. 754), and in the Keuper of the Venetian Alps (Catullo in 'N. Ann. Scienz. di Bologna,' 1846, Febbr.), is very doubtful.

Thuringia.—The published notes on the occurrence of *Estheria minuta* in the Thuringian Trias are as follow:

1849. Herbst ('Neues Jahrbuch, f. Min.,' 1849, p. 545) refers to *P. minuta* being met with in the Keuper of Weimar.

1856. Dr. J. G. Bornemann has treated of *Posidonia minuta* in his work 'Ueber organische Reste der Lettenkohlengruppe Thüringens,' 4to, Leipsic, 1856, p. 179, and figures it (indifferently) in his plate 1, fig. 9. It occurs, he says, at Johannisthal, near Mühlhausen, and elsewhere, in great numbers on the surface-planes of the Myacites-clays of the Letten-coal group, associated with *Trigonia transversa*,[1] Bornem., and *Myacites letticus*, Bornem., and in a similar state of preservation; and also in the black-grey shales which accompany the Lettenkohle, but in bad preservation. It reaches generally to about three millemetres in length. *Venus donacina*, Goldf., and *Lingula tenuissima*, Bronn, with remains of *Acrodus Gaillardoti*, Ag., and teeth of *Placodus* also occur in the Myacites-clays.

1857. In a paper on the Entomostraca of the Trias of Thuringia, in the 'Zeitschrift deutsch. geol. Gesellschaft,' vol. ix, p. 198 (1857), K. von Seebach mentions the occurrence of *Posidonomya minuta*, Bronn, in marls, immediately underlying the Lettenkohle of the Keuper, at the Gelmerodaer Berg and elsewhere, near Weimar, where it is accompanied with *Acrodus Gaillardoti*, Ag., *Colobodus varius*, Gieb., Plant-remains, *Myophoria transversa*, *Myacites*, *Cythere*[2] *Pyrus*, Seeb., *C. procera*, Seeb., *C. teres*, Seeb., and *C. dispar*, Seeb.

[1] This is the *Lyriodon vulgare*, Goldfuss, 'Petref. Germ.,' ii, p. 198, pl. 135, fig. 16, *c*.

[2] Von Seebach terms the first three of these Entomostraca *Bairdiæ*, but to me they do not appear to belong to that subgenus.

In the marls of the Muschelkalk of the same district, von Seebach also found *P. minuta*, with *Gervillia socialis*, Wism., *Colobodus varius*, Gieb., and casts of *Cytheres*.

Hanover. Dr. Volger, of Göttingen, mentions in the 'Neues Jahrbuch f. Min.,' 1846, p. 818, the occurrence of *Posidonomya minuta* in the neighbourhood of Göttingen, at Ellichausen, in the Upper Keuper, and near Abbecke in the Solling, not far from Dassel,[1] in the Upper Bunter Sandstone (laminated sandstone, alternating with marl-beds), in great numbers; and he suggests, "may it not be a bivalved Crustacean?"

In 1860. Baron von Strombeck, of Brunswick, described the position of the beds containing *Estheria minuta*, near Salzgitter, Hanover, in his paper[2] on the Myophoria-beds, published in the 'Zeitschrift der deutsch. geol. Gesellschaft,' vol. xii. From information derived from Herr Schloenback, the following series of beds is said to be observed at the foot of the Greif and at the Salgenteich, near Salzgitter[3] (p. 387).

Variegated Keuper-marl.
Lettenkohle, 1 inch.
Greyish-yellow, micaceous, and argillaceous sandstone, alternating with dark-blue laminated clay. *Myophoria pes-anseris, M. transversa, Lingula tenuissima,* and *Posidonomya minuta.*
Reddish-brown clay; in its upper part a limestone (2 feet thick), containing *Myophoria Struckmanni, M. pes-anseris,* and *Ammonites* (*Ceratites*) *nodosus*: 20 to 50 feet.
Muschelkalk.

Close to Lüneberg,[4] at, and near the Schafweide, the section appears to be from von Strombeck's account (p. 381, &c.)—

Variegated Keuper-marl.
Laminated clay (with *Lingula tenuissima*), alternating with thin beds of limestone, full of pseudomorphic salt-crystals.
Dolomitic beds,[5] with *Myophoria pes-anseris* and *Ammonites nodosus.*
Dark greenish-blue clay: 100 feet.

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[1] In the valley of the Sollen, twenty-three miles north-north-west of Göttingen.

[2] 'Ueber die Trias-Schichten mit *Myophoria pes-anseris,* Schlot., auf der Schafweide zu Lüneburg.'

[3] See the geological map of this district, in 'Karsten's Archiv,' xxvi, pl. 1.

[4] For a map, see 'Zeitsch. deutsch. geol. Gesell.,' 1853, vol. v, pl. 11.

[5] Belonging, according to the author, to the Lettenkohle-group, and not to the Upper Muschelkalk. See also Von Strombeck's paper 'Ueber das Vorkommen von *Myophoria* (*Trigonia, Lyriodon*) *pes-anseris,* Schlot., sp.' 'Zeitsch. d. deutsch. geol. Ges.,' 1858, vol. x, p. 80, &c. In this memoir (p. 86), *Posidonomya minuta* is said to occur here and there in the Myophoria-beds, but not abundantly, in company with *Myophoriæ, Myacites letticus, Gervillia socialis, Pecten Albertii, Lingula tenuissima,* &c. The last mentioned is figured in Bronn's 'Lethæa Geognost.,' vol. ii, part 3, p. 51, pl. 13, fig. 6. At Lüneburg, it has not so sharp an umbo as in Bronn's figure. It occurs plentifully on the surface-planes of the shales, and occasionally in the other beds, and always preserves its brownish thin shell (contrasting

Estheria minuta in France (*Alsace*).

In the 'Jahrbuch für Mineral.' &c., 1832, p. 227, F. von Alberti says :—"A year ago I was in Strasburg, and I saw in the museum there *Lingula tenuissima*, *Posidonia minuta*, Goldf. (*P. Keuperina*, Voltz ?), *Avicula subcostata*, Goldf., and *Calamites arenaceus*, Brongn., from the Bunter Sandstone of the neighbourhood of Sulzbad.[1]

In the 'Mém. Soc. Hist. Nat. Strasbourg,' 1837, vol. ii (see also the 'Jahrb. f. Min.,' 1838, p. 340), Voltz mentions the occurrence of the following fossils in the Middle Bunter Sandstone[2] of Soultz-les-Bains. Saurian remains (*Odontosaurus Voltzii*, Meyer, &c.), Crustaceans (*Gebia? obscura*, Mey., *Galathea audax*, Mey.), *Pecten discites*, Schl., *Posidonia minuta*, Bronn, *P. Albertii*,[3] Voltz, *Mya ventricosa*, Schl., and abundant Plant-remains.[4]

I have seen some French specimens of *Estheria minuta*, by the kindness of Professor W. P. Schimper, and his friend M. Engelhardt, of Niederbronn.

1. From *Corcelles* (*Haute Saône*). From the Lettenkohle, "*Estheria Keuperiana*, Voltz," on the bed-planes of black laminated lignite; the shell flattened, slightly wrinkled, retaining its ridges and interspaces (best seen on some impressions), and changed into a white siliceous (?) substance, with faint traces of structure. From MM. Engelhart and Schimper.

2. From *Oberbronn* (*Bas-Rhin*). Brown dolomite, like that of Sinsheim and Haigerloch, weathering ochreous ("Marnes dolomitiques du Muschelkalk, Lettenkohlegruppe). Scattered casts (chiefly of the closed carapace); some bare, some with a whitish film of shell. From Dr. W. P. Schimper.

3. From *Soulz-les-Bains* (*Bas-Rhin*). In greenish grey and yellowish-grey shale, more or less micaceous. From Dr. W. P. Schimper, of Strasbourg. These *Estheriæ*, occurring on the planes of bedding, and mostly crushed, appear in some instances to have

with the casts and impressions of the other fossils). It is peculiar to the Lettenkohle-group according to von Strombeck (p. 86); but Bronn seems to give it a larger range ('Leth. Geog.' ii, p. 51). See also above, p. 47.

[1] Soultz-les-Bains (also Soultz-à-Bains and Sulzbad), in France (Dép. du Bas-Rhin), about twelve miles west of Strasbourg. For the geological features of this place and its vicinity, see A. Daubrée's 'Description Géologique et Minéralogique du Département du Bas-Rhin,' 8vo, 1852, with map and sections. Hogard's 'Descript. Minéral. et Geol. des Regions Gran. et Arén. Syst. des Vosges,' 1837, treats of this locality, and gives geological sketches and sections of the neighbourhood. Voltz also described the geology of the Vosges in the 'Mém. Soc. Hist. Nat. Strasbourg,' 1837, vol. ii.

[2] The Upper Bunter Sandstone of Sulzbad is stated by Voltz to contain fossils of the Muschelkalk, without Plant-remains. Voltz's Lower Bunter Sandstone is now known as the Vosges Sandstone (Grès de Vosges), probably of Permian age.

[3] The particular distribution of these fossils in their strata can be better followed by a study of M. Daubrée's 'Descript. Géol. Bas-Rhin,' 1852, p. 116, &c.

[4] *P. Albertii* is described by Voltz, in a foot-note, at p. 7 of his memoir, as having the ventral border sinuous, and being longer than the *P. minuta*, but quite as small. This appears, however, to have been a variety, or a distorted individual.

a somewhat narrower outline than is usual with *E. minuta*. See Pl. V, fig. 9. This may be the form indicated by Voltz as *Pos. Albertii;* if so we may distinguish it as *E. minuta*, var. *Albertii*.

The occurrence of *Estheria minuta* at two horizons in the Triassic Series of the Lower Rhine, is clearly indicated by Prof. A. Daubrée in his admirable 'Description Géologique &c. du Departement de Bas-Rhin,' 1852.

M. Daubrée has courteously replied to my inquiries respecting the Estherian strata of Alsace, and put me in communication with Prof. W. P. Schimper, who has obligingly favoured me with specimens and information.

In the district referred to, the Triassic strata, underlying the "Lias Sandstone with bones of Reptiles and Fishes," are thus enumerated:

Keuper. (At Oberbronn,[1] 'Géol. Bas-Rhin,' p. 127).	Marls and dolomites, alternating (four mètres); among them is a dolomitic marl containing impressions of bivalve shells (*Estheria minuta* and *Lingula tenuissima*).	
	Blackish marls and blackish micaceous schists, with carbonaceous remains of plants: four or five mètres.	
	Red and grey marls and dolomites, with some sandy beds.	
	Yellowish micaceous sandstone and dolomite, with undeterminable casts of bivalves.	
Muschelkalk. (Alsace; *Op. cit.*, p. 118, 119.)	Dolomites, interstratified with marls.	
	Fossiliferous limestone, with marly partings.	
	Dolomites. (Wellenkalk.)	
West of the Vosges, at Saltzbronn; *Op. cit.*, p. 120.	Red and green clays, with gypsum and rock-salt.	
At Soultz-les-Bains; *Op. cit.*, p. 102.	Passage-beds of the Muschelkalk. Beds of crystalline dolomite, with thin bands of shale.	
Grès Bigarré or Bunter Sandstone. (*Loc. cit.*) — Upper.	Sandstone, in bands from eight to twenty inches thick, alternating with laminated clays and dolomites (each in bands from four to eight inches thick), forming a yellowish and reddish series of fine-grained sands and clays.	About fifty feet.
Grès Bigarré or Bunter Sandstone. (*Loc. cit.*) — Lower.	Fine-grained sandstones, reddish, yellowish-brown, and greenish grey (redder below, greyer above), with ferruginous streaks, in beds of from twenty inches to eight feet thick, separated by thin beds of laminated sandstone and shaly clay. *Estheriæ.*	About forty feet.

Passage-bed. Red pebbly sandstone.
Vosges sandstone (= Permian).

"In the quarry at Soultz-les-Bains, which has been the most productive, the beds lying over the sandstones worked for building-stone, contain very few remains of plants, but

[1] Two miles south-west of Niederbronn, and seventeen miles and a quarter south-west of Wissembourg.

abundance of marine shells and remains of Saurians. Beneath these, the upper bed of the sandstones that are worked contains fossil wood and *Calamites*. The clay-band that succeeds contains impressions of Ferns and Conifers. It is in the clay-bands covering the lower bed of stone, or the third, that one meets with the most numerous and best preserved impressions of plants. In the clays the most delicate parts of the plants are admirably preserved. One of these lower clay-bands is covered, so to say, with *Posidonomya minuta*; another exhibits the impressions of two crustaceans belonging to the genera *Branchipus* and *Apus*.[1]" (p. 116.)

In 1853 W. P. Schimper mentioned *Posidonomya minuta* in his 'Notes on the Xiphosures of the Trias of Alsace,' forming part of his 'Palæontologica Alsatica,' in the 'Mém. Mus. Nat. Hist. Strasbourg,' 1853, vol. iv. At p. 7 speaking of the *Apudites antiquus*, Schimp. (pl. 3, fig. 2—4), he says, it occurs in numbers in all positions, is wonderfully like the recent *Apus cancriformis*, that annually swarms in some of the pools of the neighbourhood of Strasburg; it is found in argillaceous beds together with *Posidonomya minuta* in the upper part of the Grès bigarré at Soultz-à-bains in the Departement du Bas-Rhin. A *Limulus* (*Limulites Bronnii*) was found in 1851 in the Grès bigarré, near Wasselonne, about ten miles from Strasburg.

Estheria minuta? in the Trias of Northern Italy. In the 'Nuovi Annali Scienz. Nat. Bologna,' 1846, Febbr., Prof. T. A. Catullo mentions the occurrence of *Posidonomya minuta* in the Venetian Alps (See Bronn, quoted above, p. 50). *Posidonomya Wengensis* and *Avicula globulus*, mentioned at page 13 as small bivalves, of doubtful relationship, occurring in the St. Cassian beds of the Tyrol, may be again referred to here.

[1] Schimper and Mougeot, 'Monogr. Plantes Foss. Grès Bigar.,' 1844, p. 5; and 'Mém. Mus. Hist. Nat. Strasbourg,' vol. iv, p. 7.

The following Table shows, in chronological order, the chief recorded occurrences of *Estheria minuta* in the Trias of Germany and France, and the geological horizons in which it has been found:

Date.	Estheria minuta.	Authority quoted.	Author or observer.	Locality.	Geological stage.
1832	Posidonia Keuperiana	Voltz	Dechen	Hall (Würtemberg)	Lettenkohle group.
1832	P. minuta	Alberti	Dechen	Rottweil (Würtemberg)	Lettenkohle group.
1832	P. Goldfussii	Alberti	Dechen	Hall (Würtemberg)	Lettenkohle group.
1832	P. minuta	Goldfuss	Alberti	Sulzbad (Bas-Rhin)	Lower Bunter.
1832	P. Keuperina	Voltz	Alberti	Sulzbad (Bas-Rhin)	Lower Bunter.
1833	P. minuta	Alberti	Zieten	Rottweil (Würtemberg)	Lettenkohle group.
1834	P. minuta	Goldfuss	Alberti	Rottweil (Würtemberg)	Lettenkohle group.
1834	P. minuta	Goldfuss	Alberti	Rottenmünster (Würtemberg)	Lettenkohle group.
1834	P. minuta	Goldfuss	Alberti	Rietheim (Würtemberg)	Lettenkohle group.
1834	P. minuta	Goldfuss	Alberti	Bieberfeld (Würtemberg)	Lettenkohle group.
1834	P. minuta	Goldfuss	Alberti	Sulzbad (Bas-Rhin)	Lower Bunter.
1834	P. minuta	Goldfuss	Alberti	Corcelles (Haute-Saône)	Lettenkohle group.
1834–40	P. minuta	Goldfuss	Goldfuss	Hassfurth (Bavaria)	Lettenkohle group.
1834–40	P. minuta	Goldfuss	Goldfuss	Heilbronn (Würtemberg)	Lettenkohle group.
1834–40	P. minuta	Goldfuss	Goldfuss	Pforzheim (Baden)	Lettenkohle group.
1835–8	Posidonomya minuta	Bronn	Bronn	Täbingen(Würtemberg)	Upper Keuper.
1835–8	Posidonomya minuta	Bronn	Bronn	Sinsheim (Baden) (and other places mentioned in this table)	Lettenkohle group.
1837	Posidonia minuta	Bronn	Voltz	Sulzbad (Bas-Rhin)	Lower Bunter.
1837	Posidonia Albertii	Voltz	Voltz	Sulzbad (Bas-Rhin)	Lower Bunter.
1843	Posidonia minuta	—	Quenstedt	Würtemberg	Lettenkohle group.
1846	P. minuta	—	Catullo	Venetian Alps	?
1846	Posidonomya minuta	—	Volger	Elliehausen (Hanover)	Upper Keuper.
1846	Posidonomya minuta	—	Volger	Abbecke (Hanover)	Upper Bunter.
1849	Posidonomya minuta	—	Herbst	Weimar (Thuringia)	Lettenkohle group.
1851	Posidonomya minuta	Bronn	Bronn	(See above)	—
1852	Posidonia minuta	Alberti	Daubrée	Oberbronn (Bas-Rhin)	Keup. & Lettenkl.
1852	Posidonia minuta	Alberti	Daubrée	Sulzbad (Bas-Rhin)	Lower Bunter.
1853	Posidonomya minuta	—	Schimper	Sulzbad (Bas-Rhin)	Lower Bunter.
1856	Posidonia minuta	Alberti	Bornemann	Johannisthal (Thuringia), &c.	Lettenkohle group.
1857	Posidonomya minuta	—	Seebach	Weimar (Thuringia)	Lettenkohle group.
1860	Posidonia minuta	—	Strombeck	Salzgitter (Hanover)	Lettenkohle group.

We may add Gersfeld (see p. 45) as a locality for *E. minuta* in the Bunter, Haigerloch (Hohenzollern), Nimburg (Breisgau), and Weyhers and Fulda (Bavaria), as other localities for *E. minuta* in the Lettenkohle group, (see p. 44 and p. 45); also Durlach (Baden) and Weyhers (Bavaria) as localities for *E. minuta* in the Muschelkalk, and Halle (Thuringia) for *E. minuta* in the Keuper (page 45).

Table showing the occurrence of Estheria minuta *in the various members of the European Trias.*

Members of the Trias.	England.	Eastern France.	Baden, Würtemberg, and Bavaria.	Hanover.	Thuringia.
Upper Keuper	*	—	Täbingen	Elliehausen, &c.	—
Lower Keuper	—	—	—	—	Weimar.
Lettenkohle	—	*	*	Salzgitter	Johannisthal, &c.
Muschelkalk	—	—	Durlach	—	Weimar.
Upper Bunter	—	—	Gersfeld	Dassel, &c.	—
Lower Bunter	—	*	—	—	—

This Table is constructed on imperfect grounds, and therefore is only offered as a provisional synopsis. I have not seen specimens from the places the names of which are given in the Table, and which have been referred to as localities for the *Estheria* in certain zones. The *asterisks* indicate the zones in the several districts from which I have had specimens under examination.

Habitat of Estheria minuta.—In Alsace, Baden, Würtemberg, Bavaria, Thuringia, and Hanover, the *Estheria minuta* is associated with *Lingula tenuissima*, a marine shell, subjected however to the deteriorating influence of fresh water, if the observations on this point at page 48 bear me out. Other marine molluscs also, such as *Myacites*, *Gervillia Trigonia* or *Myophoria*, *Pecten*, and *Pleurophorus*, accompany *E. minuta*, at various localities over this wide district, occurring, for the most part, however, in beds amongst which the Estherian shales are occasionally intercalated. The general occurrence of the *Estheriæ* in interlaminated shaly beds, strengthens the opinion that they existed chiefly at the intermediate periods when the fresh water had gained some predominance in the shallow seas or lagoons. In the Bunter Sandstone of Alsace, land-plants occur in the Estherian clays; but here, whilst the freshwater *Apus* is one of the associates of *Estheria*, a *Limulus* intrudes itself in accompanying strata of the same age. (See p. 54).

In some of the beds of the Keuper, crystals of salt have left their casts abundantly, showing both the saltness and the shallowness of the seas or lakes in which the upper Keuper beds were deposited. But however near to these salt-bearing beds the *Estheriæ*

occur, they are never found in them. Such pseudomorphic salt-crystals occur near Lüneberg, in the shales with *Lingula tenuissima*, alternating with the limestones, just above the Lettenkohle group; in the dolomitic beds of which latter *Estheria minuta* occurs (sparingly) with *Myophoriæ*, &c. (See page 51.) So again, in England, the pseudomorphic salt-crystals occur in the Upper Keuper shales immediately overlying the grey sandstones and shales containing *Estheriæ*, but not in the Estherian shales themselves.

Estheria minuta of the English Trias.

In the New Red Sandstone of England *Estheria minuta* is abundant at places, and often occurs as well-grown individuals (larger than any from the Continent that I have yet had an opportunity of seeing), and occasionally (as at Pendock) most perfectly preserved. Judging from the materials at my command, I may say, that the English specimens are more variable in their shape than those found in Germany, since they are apt to contract the posterior portion of the carapace-valves, and so take a subovate form; but I cannot say that such a variation of outline may not be found in the foreign specimens, of which I have not seen a very large series.

The beautifully perfect condition of the carapace in Pl. II, fig. 1, is strongly contrasted, in its neatly definite concentric ridges, and the smooth broad intervals, delicately reticulated by large fine-walled meshes, with the obscurely wrinkled stony casts, indicated by figs. 4 and 5, and with the coarse-walled meshes into which the original reticulation is here modified, the animals having been fossilized in a less accommodating matrix. The German specimens (Pl. I, figs. 28—30) have suffered similar deteriorations.

The measurements of some of the best English specimens are as follow:

From Pendock	Height, rather more than $\frac{1}{12}$ inch Length of valve ..... $\frac{2}{12}$ „ Thickness of closed valves, less than ..... $\frac{1}{12}$ „	Proportion, 2 to 3 by 1, or 1 to $1\frac{1}{2}$ by $\frac{1}{2}$.
From Shrewley Common and Pendock	Height ..... $\frac{1}{6}$ $\frac{2}{12}$ „ Length ..... $\frac{1}{4}$ $\frac{3}{12}$ „ Thickness rather less than $\frac{1}{12}$ „	Proportion 6 to 9 by 4, or 1 to $1\frac{1}{2}$ by $\frac{3}{4}$.
From Somerton	Height, rather less than $\frac{2}{12}$ inch Length ..... $\frac{2}{12}$ „	Proportion 23 to 30, or 1 : $1\frac{1}{3}$+

In my examination of English specimens of *Estheria minuta*, I have had before me specimens from the Upper Trias, or Keuper, of Somersetshire, Worcestershire, Warwickshire, and Leicestershire.

1. A specimen of pinkish-white, fine-grained sandstone, from Shrewley Common, Warwickshire, with convex casts of *Estheriæ*, retaining traces of the shell and its ornament (Pl. II, figs. 5—7), collected by the late Mr. H. E. Strickland, and presented by

him to the Geological Society. This specimen served for an illustration in the 'Geol. Transact.' (2nd ser., vol. v, pl. 28, fig. 4) to the memoir by Strickland and Murchison on the New Red Sandstone. There are numerous *Estheriæ* on a plane of bedding, both large and small; one of the largest is here figured (fig. 5).

Other specimens of sandstone slabs bearing *Estheria minuta*, associated with greenish shale, collected by the Rev. P. B. Brodie, F.G.S., at Shrewley and Rowington, are in the Museum of the Geological Society, in the British Museum, and in the Museum of Practical Geology, Jermyn Street.

2. Compact grey shale, from Pendock, Worcestershire, containing scattered specimens of *Estheria minuta*, often in a most perfect state of preservation. The shell is of a delicate honey colour. These have been collected and liberally communicated by the Rev. W. S. Symonds, F.G.S. The specimen figured (Pl. II, fig. 1) belongs to Professor Tennant, F.G.S.

3. Mr. James Plant, of Leicester, has confided to me some greenish-grey laminated sandstone, with a very few scattered casts of *Estheria minuta*, retaining some of the carapace, from near Leicester. See page 63.

4. Grey fine-grained sandstone, from Somerton, Somersetshire, bearing, in one specimen, numerous convex casts of *Estheria minuta*, both of large size (fig. 4), and small, with traces of the shell remaining; in another specimen crowded and crushed carapaces of *Estheriæ*, and also convex casts with scarcely any shell, all of small size. In both cases the *Estheriæ* lie on the plane of bedding. Mr. Charles Moore, F.G.S., has discovered and lent these interesting specimens.

5. Other English localities for *Estheria minuta* (as I learn by specimens in the Museum of Practical Geology, Jermyn Street) are—

Hill End, between Eastington and Castle Morton, east of the southern part of the Malverns (See 'Mem. Geol. Surv.,' ii, I, p. 120, &c., and map). Coarse greenish-grey sandstone. Collected by Professor Phillips.

Railway-cutting, at High House, near Warwick. Laminated sandstone, in green shale. Mr. Gibbs.

Newent, Gloucestershire. Laminated sandstone, in green shale. Mr. Gibbs.

Needwood Forest. Whitish micaceous sandstone,[1] weathering ferruginous. Mr. Howell.

Moreton-Bagot.[2] Grey sandstone. Mr. J. W. Kirshaw.

Shelsley, Worcestershire. Green shale.

I. *Warwickshire.*—In a memoir, published in 1840 ('Trans. Geolog. Soc.,' 2nd ser., vol. v, part 2), Messrs. Strickland and Murchison described the New Red Sandstone series of Worcestershire, Gloucestershire, and Warwickshire, as consisting of—

[1] The specimens are obscure casts here; and there is some doubt as to whether this sandstone belongs to the Triassic or the Rhætic series.

[2] "North of the fault," Mr. Kirshaw tells me.

Keuper	Red marl	30 to 40 feet thick	At the canal-tunnel in Shrewley Common.
	Fossiliferous sandstone and green marl	20 „	
	Red and variegated marl	10 „	

Calcareous band.

Bunter Sandstone;[1] occurring at Ambersley, Bromsgrove, and Warwick; also in Cheshire and Shropshire (Grinshill, Hawkestone).

After pointing out the uniform extent of the Keuper Sandstone throughout Worcestershire, Gloucestershire, and Warwickshire, and in which occurs the so-called *Posidonomya minuta*, they remark (p. 337)—

"The exact geological position of this sandstone, which we consider to be the equivalent of the Keuper Sandstone of Suabia and Alsace, is 200 or 300 feet below the lowest beds of the Lias—a position which coincides well with that of the principal mass of this sandstone in Wurtemberg, where one of the authors has examined it. In Germany, however, the Keuper formation contains several courses of sandstone and grit, but always subordinate to thick masses of marl. In England, we have one well-defined band only, which, occurring from 200 to 300 feet below the Lias, is completely and distinctly separated from the Great Red Sandstone of the central counties by a vast thickness of red and green marls, which in certain tracts are saliferous. . . . . .

"The Keuper of England (on the whole quite as largely developed as that of Germany) is, like the 'Marnes Irisées' of France, a great marly formation, with one principal band of sandstone[2] subordinate to it, which sandstone is separated by at least 600 feet of marls from the great mass of the underlying New Red Sandstone (Bunter Sandstone)."

In speaking of *Estheria minuta*, which occurs at Shrewley Common, in company with the spine of *Hybodus Keuperianus* (termed *Keuperinus*, at p. 388), "two small teeth of squaloid fish," reptilian foot-tracks, and ripple-mark, they say (p. 338)

"The bivalve shells (pl. 28, fig. 4) appear to be the *Posidonomya minuta* of Bronn ('Lethæa Geognostica,' p. 164, pl. 11, fig. 22), or the *Posidonia minuta* of Goldfuss ('Petrefacten,' pl. 113, fig. 5), and of Zieten ('Versteinerungen Württembergs,' pl. 54, fig. 5)."[3]

And they proceed to observe that—

"In Germany this shell is stated to pervade[4] the New Red system from the 'Keuper' to the 'Bunter Sandstein' inclusive; but in this country it appears peculiar to that band of sandstone which we have proved by stratigraphical evidence to represent the upper formation. It is indeed a very characteristic shell; for, as previously stated, we

[1] The more modern and correct classification of these beds is given further on, at p. 62.

[2] See Mr. Hull's remarks on the Keuper Sandstone of the Midland Counties further on, p. 64.

[3] "Bronn has changed the generic name to *Posidonomya*, the term *Posidonia* being preoccupied in botany. Capt. Portlock has lately detected this shell in the New Red Sandstone of Roan Hill, near Dungannon, Ireland." (See p. 40 of this monograph.)

[4] This is not correct; see the account of the German Trias above, pp. 46 *et seq.*

have detected it at Burge-hill and Inkberrow, in Worcestershire, and at Shrewley Common, in Warwickshire, where it is very abundant in some of the sandstone beds."

One of the specimens of *Estheria minuta* from Shrewley is figured in Pl. II, figs. 5—7; see page 57.

The Rev. P. B. Brodie, F.G.S., in his paper "On the Upper Keuper Sandstone (included in the New Red Marl) of Warwickshire," 'Quart. Journ. Geol.,' 1856, vol. xii, p. 374, &c., observes that—

"The slabs with *Posidonia* occur plentifully along the banks of the canal near Shrewley, in green marls and sandstone, a few feet above the Inferior Red Marl; but the specimens are best preserved in the sandstone;" and he gives the following section seen on the banks of the canal at Shrewley in descending order:

1.	Green marl	3 or 4 inches.
2.	Beds of grey and light-coloured fine-grained sandstone, divided by marl; with *Posidonia minuta* and ripple-marks. In the middle occurs a coarse gritty sandstone, with white specks (less coarse than at Pendock, in Worcestershire), which contains bones, teeth, and spines of *Acrodus* (or *Lophodus*)	1 foot 9 ,,
3.	Green marl	0 ,, 2½ ,,
4.	More finely grained sandstone, more or less ripple-marked; with footsteps of *Labyrinthodon*	2 feet 3 ,,
5.	Green marl	0 ,, 2 ,,
6.	Hard workable sandstone ("bottom-bed"), the only good building-stone of the locality; with imperfect casts of *Posidonia*	3 ,, 6 ,,
7.	Thin beds of sandstone, divided by green marls; with remains of plants (*Voltzia*, *Calamites* (?), and *Fucoides* (?). This is best seen at Rowington	10 ,, 0 ,,
8.	Red marl.	

In 1857 Mr. Brodie gave a notice ('Quart. Journ. Geol. Soc.,' vol. xiv, p. 165) of the discovery of a fossil fish (*Palæoniscus superstes*, Egerton) in the Upper Keuper Sandstone at Rowington, Warwickshire, about twelve miles from Shrewley Common; and as there is some interest belonging to the association of fish-remains with *Estheria* in the section at Rowington, which is comparable with that above given, and as Mr. Brodie has favoured me with a note on the occurrence of *Estheriæ* in these beds, I here subjoin a description of the Rowington Section.

"About half way down the hill on which the church (Rowington) stands are certain kinds of brashy stone, more or less sandy and marly, and having a very irregular fracture; in these I discovered the new fish which Sir Philip Egerton has described above under the name of *Palæoniscus superstes*. The vicinity of the vicarage affords the following section in descending order:

	Feet.	Inches.
Thin beds of sandy stone,[1] in green marl; brashy bed	2	0
Sandstone / Green marl / Sandstone	0	11
Green marly stone, with so-called "Fucoid" impressions	0	6
Several beds of ripple-marked sandstone, thickness not exposed.		

"At a somewhat lower level on the canal-bank, at the west end, the section is continued as follows:

	Feet.	Inches.
Beds of rubbly sandstone and marl, much broken; with remains of Plants	5	0
Grey sandstone, divided by green marls, full of Fucoids?	10 to 12	0
Hard sandstone[2]	4	0
Green shaly marl (a few inches).		
Red marl."		

Mr. Brodie has also kindly communicated to me by letter (January 1861) the following information.

"As to the *Palæoniscus*, I found it in some green marly shales, higher than the shales containing *Estheriæ* most abundantly, which usually occur near the base of the Keuper, just above the red marls. I have not seen *Estheriæ* in these marls, although they may occur.

"*Estheria* occurs abundantly in the thick sandstones at the bottom, as well as in the green marls which underlie it, but more sparingly in the beds above, and in some bands it is not met with at all. The chief repositories of these Crustaceans is in the thick sandstone and the green marls, and sandstone above both. They are best preserved in the marls."

II. *Worcestershire.*—In 1855, the Rev. W. S. Symonds, F.G.S., mentioned the occurrence of "*Posidonomya minuta*" in the Keuper Sandstone of Pendock, Worcestershire. The following are the particulars of the section, as published in Mr. Symonds' paper in the 'Quart. Journ. Geol. Soc.,' vol. ix, p. 450:

The Keuper Sandstone quarry, from which the fossils here referred to were obtained, is situated in the village of Pendock, about three miles from the base of the south end of the Malverns, and exactly opposite the Holly Bush Pass. These sandstones are quarried to the depth of fourteen or fifteen feet. They dip under the Upper Red Marls and Lower Lias of the Berrow Hill, at an angle of from 5° to 6°. Their position as regards the Bone-bed, at the base of the Lias, cannot be less than from 250 to 300 feet below that deposit.

[1] The *Palæoniscus superstes* occurred in this bed.

[2] Another specimen of *Palæoniscus* has been found in the lowest bed of the Keuper Sandstone here.

The section in the quarry exhibits the following series:

	Feet.	Inches.	
Surface-soil	2	6	
Marl	2	6	*Estheriæ.*
Sandstone		7	Fish-teeth.
Marl		5	*Estheriæ.*
Sandstone		6	
Marl		1	
Sandstone		5	
Osseous conglomerate, or Bone-bed		1½	Fish-teeth and bones (*Lophodus, &c.*).
Marl and thin sandstone	1	6	*Estheriæ.*
Thick sandstone and marl. Thickness unknown			Plants (*Equisetites* or *Calamites*). (Plant-remains occur also in the other beds.)

A specimen from this quarry is figured in Plate II, figs. 1—3; see page 57.

Mr. Symonds has also informed me by letter, dated February 2nd, 1861, that the same little fossil shells were found at the eastern entrance of the Malvern tunnel,[1] on the Worcester and Hereford Railway, in grey shales associated with sandstones, and belonging to the same series of beds as those of the Pendock section, namely, the Upper Keuper Shales and Sandstones.[2] *Estheria* is here associated with teeth and spines of *Lophodus*. The Keuper beds of this district east of the Malvern range were described in 1848, in the 'Memoirs Geol. Survey,' vol. ii, part 1, pp. 119, &c., by Prof. Phillips, who found *E. minuta* at Hill End (see page 58).

The following approximative section of the New Red Sandstone of Worcestershire has been drawn up with the kind help of Mr. George E. Roberts, author of 'The Rocks of Worcestershire,' &c., &c.:

		Feet.
Upper Keuper.	1. Upper Keuper (grey and red) Marls, with pseudomorphic salt-crystals. (Well seen at Crowle, 4 miles east of Worcester)	40
	2. Upper Keuper Sandstone with *Estheria*, Plant-remains, and Fish-remains. (Well seen at Pendock)	20
	3. Lower Keuper (red) Marls: Upper variegated marls. Pseudomorphs of salt and gypsum in the upper portions. (Worcester Railway-station)	1000
	3. Lower Keuper (red) Marls: Lower red marls; saliferous. (Droitwich)	

[1] See the section published in the 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 154.

[2] The order of the Triassic beds in this district are—

1. Upper Keuper (grey and red) Marls (with pseudomorphic salt-crystals).
2. Upper Keuper Sandstones (with *Estheriæ* and Fish-remains).
3. Lower Keuper (red) Marls.
4. Lower Keuper Sandstone (equivalent to the "water-stones"). See 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 152.
5. Upper Red Sandstone (Bromesberrow beds).
6. Lower Red Sandstone (Stourport beds).

		Feet.	Feet.
Lower Keuper.	4. Lower Keuper Sandstone (including the water-stones):		
	1. Reddish sandstone, micaceous; with Plant-remains (Ombersley, Bellbroughton)	20	
	2. Cupriferous sandstone, micaceous (Ombersley, Hadley, Bellbroughton)	200	
	3. Thin-bedded sandstone, red and white, micaceous (Drayton, Bellbroughton)	30	
	4. Thin, greyish, calcareous bands, magnesian (?) (Drayton)	6	
	5. Breccia, somewhat calcareous, reddish 6. Conglomerate, red (Hartlebury)	60	316
Bunter—			
	5. Upper soft red sandstone (Bromesberrow)		200
	6. Reddish conglomerate, variable in constitution (Kidderminster and Wolverley)		400
	7. Lower soft red sandstone (Habberley and Stourport)		200

III. *Leicestershire.*—In a paper on "The Upper Keuper Sandstone (included in the New Red Marls) and its Fossils at Leicester," 1856, 'Quart. Journ. Geol. Soc.,' vol. xii, p. 369, &c., Mr. James Plant gives the following section of the strata (p. 372), and note on the fossils. Amongst the latter is *Estheria minuta.*

Upper Keuper.

a. Upper Keuper Marls, containing beds of gypsum and several thin bands of green marly sandstone, on which are found numerous pseudomorphic salt-crystals; thickness from 80 to 120 feet.

b. Thin sandy shales, with way-boards of green marl; 25 to 30 feet.

c. Thick beds of soft white sandstone; 20 to 30 feet.

d. Thin sandy shales, similar to *b*; 35 feet (in laminæ, varying from half an inch to four inches in thickness). *Estheriæ.*

Red clay.

Fossils found in these Upper Keuper beds:

Plants.—Casts of *Echinostachys oblongus* and *Equiseta*; remains of *Voltzia* and *Algæ* (?).

Annelids.—Cololites and casts of tubes.

Estheria minuta, found in the green marls and thin sandy shales of beds *d* (rare). Found at Dane Hill, and Belgrave, Leicester.

Fishes.—Teeth of Placoid fishes; Ichthyodorulites; fragments of Bones; Coprolites (?); in beds *c* and *d.*

Sand-casts of salt-crystals, and traces of Corallines (?) in beds *a.*

Mr. Plant has kindly submitted some specimens of the laminated sandstone, with *Estheria minuta,* for my inspection (see above, p. 58); he has also informed me lately that he has met with larger numbers in a group, at a cutting two miles from Leicester, in the same beds.

IV. *Somersetshire.*—Mr. Charles Moore, F.G.S., of Bath, has met with specimens of the Triassic *Estheria,* near the following places in Somersetshire—North Curry, Taunton,

and Somerton (Pl. II, fig. 4, page 58). The section at the first-named place is described by him in the 'Quart. Journ. Geol. Soc.,' vol xvi, p. 486, as being (immediately under the Rhætic beds)—

	Feet.	Inches.
Light-blue marl	6	0
Variegated blue and red marls, with alabaster ....about	100	0
Various beds of dull grey and brown sandstone, enclosing nodules of marl, and containing *Estheriæ*, Plants, traces of Fish-scales, and a Reptilian bone.....	3	6
Blue and red marls	21	3
Red and blue compact marls ....about	40	0

These are followed by other marls and sandstone, seen at Knap, about a mile and a half distant.

At page 490, in the same memoir, Mr. C. Moore states that near Stoke-St.-Mary, "in the sides of the turnpike-road leading to Taunton, thin beds of Keuper are present with *Posidonomya minuta*."

The beds of Keuper at Somerton, Mr. Moore informs me, are of the same age as those that he has noticed at Curry, but very much thicker.

V. *The New Red Sandstone in Cheshire and Warwickshire.*—The position of the *Estheriæ* in the Trias is shown by the following table of the Triassic strata in Cheshire, for which I am indebted to my friend, Mr. E. Hull, F.G.S., one of the Geological Surveyors, who has especially studied the Triassic formation of England. The additional notes, also, which Mr. Hull has kindly communicated to me, furnish us with further information relative to the correlation of the Trias of Warwickshire with that of Cheshire.

The Triassic Group in Cheshire.

Keuper Division. Thickness, more than 3000 feet.	1. Red and variegated marls, with bands of grey and white sandstone ("Upper Keuper Sandstone"). Fossils: *Estheria*[1] and *Annelides*. (*Palæoniscus superstes*, Egerton, at Rowington, Warwickshire. *Estheriæ* and remains of Fishes and Plants in Worcestershire, Warwickshire, Leicestershire, &c.) Beds of rock-salt[2] and gypsum occur in these marls, probably towards the base. Thickness, nearly 3000 feet.
	2. Flaggy, micaceous, rippled sandstones and marls ("Waterstones" of William Smith, Binney, and Ormerod), passing downwards into white and reddish freestones, and resting on a base of calcareous breccia. "Lower Keuper Sandstone;" thickness, 450 feet. Fossils: *Cheirotherium; Annelides*. (*Rhynchosaurus*, at Grinsill, Salop; *Dipteronotus cyphus*, Egerton, at Bromsgrove; *Cheirotherium*, Derbyshire and Staffordshire).

[1] Mr. Hull informs me that the *Estheria* occurs in the bands of sandstone in the red and variegated marls; and that it is not common in Cheshire, but is more plentiful in the Midland Counties in this position.

[2] Pseudomorphs of salt occur (according to Mr. Hull) plentifully in the sandstone and the sandy

Bunter Division. Thickness, 1900 or 2000 feet.	1. Upper mottled sandstone. Soft, fine-grained, variegated sandstone, without pebbles: 700 feet. No fossils. 2. Conglomerate-beds. Red pebbly sandstone, with veins of protoxide of iron and oxide of manganese: 700 feet. Obscure impressions of drifted Plants. 3. Lower mottled sandstone. Soft variegated sandstone: 500 feet. No fossils.

In consequence of the south-easterly thinning out of the Triassic group,[1] all the divisions of the above table, as they occur in Cheshire, become reduced in thickness; and some are entirely absent in Warwickshire, as will be seen by the following synoptical comparison, kindly supplied by Mr. E. Hull.

	Cheshire.		Feet.	West Warwickshire.	Feet.	East Warwickshire.	Feet.
Keuper.	Red marl, including the Upper Keuper sandstone[2]	above	3000		600		450
	Lower Keuper sandstone	„	450		200		150
Bunter.	Upper mottled sandstone	„	700		400		
	Conglomerate-beds	„	700		400		(Absent.)
	Lower mottled sandstone	„	500		100		
			5350 (nearly)		1700 (nearly)		600 (nearly).

Habitat of Estheria minuta.—In England there are no marine organisms (fishes being excluded as doubtful witnesses) accompanying the *Estheriæ* of the Keuper; and the latter might have been at once regarded as of equally freshwater habits with their recent congeners, were it not that the salt condition of the waters depositing much of the Keuper sandstones and shales is proved by the masses of rock-salt and by the casts of the cubical crystals of salt occurring abundantly in the same beds all over the country of the

beds of the red marl in Cheshire and the Midland counties. It is desirable that we should know whether the salt-crystals and the *Estheriæ* occur in the same or in different layers in this district. Salt-pseudomorphs are described by Messrs. Strickland, Ormerod, and Smyth, in the 'Quart. Journ. Geol. Soc.,' vol. ix, pp. 5 and 187.

For special information respecting the salt-beds at Northwich, &c., see papers by Messrs. Binney and Ormerod, 'Quart. Journ. Geol. Soc.,' vol. ii and vol. iv. For remarks on the unconformability of the Keuper to the Bunter, see Mr. Hull's paper in the 'Quart. Journ. Geol. Soc.,' vol. xvi, p. 76; and for this and other points belonging to the character and distribution of the Triassic beds see the 'Memoirs Geol. Survey' (Explanations of the Maps and Sections).

[1] See 'Quart. Journ. Geol.,' vol. xvi, p. 63, &c.

[2] "With regard to the term 'Upper Keuper Sandstone,'" says Mr. E. Hull, "I think that it can only be retained as applicable to the midland counties. In the northern counties this rock is not confined to one definite zone in the red marl, but is distributed in thin layers throughout nearly the whole subdivision. While, therefore, in Worcestershire, Warwickshire, and Leicestershire (as shown by Strickland, Murchison, Brodie, &c.), we may divide the red marl into three portions, the central of which is the 'Upper Keuper Sandstone,' in Notts, Cheshire, and Salop, no such divisions are possible, as the whole is essentially one group."

Keuper. Still *Estheriæ* have not been found (to my knowledge) in these salt-bearing beds. They appear to keep a definite line above the horizon of the rock-salt and beneath that of the salt-pseudomorphs, and may represent a nearly, if not quite, freshwater condition of the waters of the Upper Triassic period for the localities in which they occur.

In Gloucestershire (near Tewkesbury), and near Pendock, and at the eastern end of the Malvern Tunnel, in Worcestershire (Prof. Morris), the salt-crystals[1] abound in the thin sandstone imbedded in greenish-grey shale above the sandstone and shale with *Estheriæ* and plants.

In Leicestershire Mr. James Plant has found the Keuper to be rich in these pseudomorphs at some places; he informs me that he has taken these salt-casts most abundantly at four localities, twenty miles apart, namely, Chilwell, Orton, Beaumanor Park, and Spinney Hills, near Leicester. In all these cases he considers the beds to be either the Upper Keuper Marls or the sandy shales immediately beneath, except at Orton,[2] where, perhaps, there are the still lower sandy shales (containing *Estheriæ*, near Leicester), lying on red marl.

ESTHERIA MINUTA, Var. BRODIEANA. Pl. II, figs. 8—15.

CYCLAS-LIKE BIVALVE, *Brodie*. Proceed. Geol. Soc., 1842, vol. v, pp. 14 and 15; Hist. Fossil Insects, Second. Rocks, England, 1845, pp. 58, 79, &c.
CYCLAS, sp., *Duff*. Geology of Moray, p. 1842, p. 19.
ESTHERIA MINUTA, *Wright*. Quart. Journ. Geol. Soc., 1860, vol. xvi, pp. 378, 387, 395.
ESTHERIA, *C. Moore*. Quart. Journ. Geol. Soc., 1860, vol. xvi, p. 446; and 1861, vol. xvii, p. 497, 512.

From Westbury	Height ..... $\frac{1}{12}$ inch Length ..... $\frac{1\frac{1}{2}}{12}$ „	Proportion, 1 : $1\frac{1}{2}$.	
„	Height, rather more than $\frac{1}{12}$ „ Length ..... $\frac{2}{12}$ „	„	9 to 16, or 1 : $1\frac{3}{4}$+
From Wainlode	Height of valve ..... $\frac{1}{12}$ „ Length, less than ..... $\frac{1\frac{3}{4}}{12}$ „ Thickness, less than ..... $\frac{\frac{3}{4}}{12}$ „	„	12 to 17, by 5; or 1 : $1\frac{1}{2}$—, by $\frac{1}{2}$—
„	Height, less than ..... $\frac{1}{12}$ „ Length, more than..... $\frac{1}{12}$ „	„	5 to 7, or 1 : $1\frac{1}{2}$—
From Linksfield	Height ..... $\frac{1\frac{1}{2}}{12}$ „ Length, less than ..... $\frac{9}{12}$ „	„	8 to 11, or 1 : $1\frac{1}{2}$—

[1] For notices by Mr. Strickland and Mr. Ormerod of the pseudomorphic salt-crystals, or rather sandstone casts of the hollows left by salt-crystals, see 'Quart. Journ. Geol. Soc.,' vol. ix, pp. 5, 187.

[2] At Orton, Mr. Plant informs me, the sandstone is only four feet thick, but is so widely spread and so horizontal that it is used in its natural position as threshing-floors in barns, and on these can be discerned the pseudomorphs and ripple-marks. Such sandstone is similarly used in Worcestershire.

This differs from *Estheria minuta* of the Trias in being smaller (frequently not much more than half the size), and in having a relatively smaller reticulation of the surface[1] (6—8 meshes between the ridges). It seems to have similar variations of shape as the type exhibits.

This variety I have named *Brodieana*, after the Rev. P. B. Brodie, F.G.S., who first noticed it in the strata formerly known as the Lower Lias Shales, and now classified as the Rhætic beds, or the passage-beds between the Trias and Lias. I have it from Somersetshire, Gloucestershire, Warwickshire, and Worcestershire (England), and from Morayshire (Scotland).

I. *Gloucestershire and Warwickshire.*—In Gloucestershire this *Estheria* occurs at Westbury Cliff, near Newnham, and at Wainlode Cliff, near Tewkesbury, both on the Severn. From the former place I have seen specimens in a light, yellowish-grey, soft, fine-grained limestone (with numerous small fragments of plants in some specimens, without them in others). It is sometimes scattered, sometimes numerous, on the planes of bedding, and is usually flattened, but sometimes retains its convexity; occasionally a specimen is seen imbedded in an upright position, showing the dorsal aspect of the carapace, more or less crushed. The specimens were collected by the Rev. P. B. Brodie and by W. R. Binfield, Esq., and are in the museum of the Geological Society. The Estherian limestone is described as occurring in nodules at a certain horizon in the section. (See pp. 69, 70.)

The specimens from Wainlode Cliff consist of a bluish-grey limestone (weathering brownish-grey), full of dark-brown *Estheriæ* (Pl. II, figs. 12—15), retaining their shell and their convex form, and lying in the matrix in every position. Some of these specimens are in the museums of the Geological Society and the Geological Survey, and others were given me by the Rev. Mr. Brodie, in February, 1861; none of them contain plant-remains, *Cypridæ*, *Unio*, nor fish-scales, such as are noted as belonging to bed No. 6 of Mr. Brodie's section, quoted at page 68; probably the *Estheriæ* occur only in the nodules (as at Westbury), and the other fossils in the accompanying clay or limestone.[2]

In November, 1842, the Rev. P. B. Brodie, F.G.S., ('Proceed. Geol. Soc.,' vol. iv, p. 14, &c.), described the strata at Wainlode Cliff, on the south bank of the Severn, near Tewkesbury, and at Westbury, near Newnham, on the Severn, eight miles below Gloucester, especially with reference to the occurrence of fossil insects in some of these beds that lie between the Red Marls of the Trias and the Lower Lias Shales. In noticing the characters and position of these strata, Mr. Brodie observed the occurrence of numerous small bivalve shells, much resembling *Cyclas*, in some of the layers; and specimens were given

[1] Much resembling that of the recent, and somewhat similar, but larger, *E. polita*, Baird, 'Proc. Zool. Soc.,' 1849, p. 88, Annul., pl. 11, fig. 3.

[2] Still more exact observations as to the distribution of *Entomostraca*, Insects, Plants, &c., in these Rhætic beds of Westbury, Wainlode, &c., are highly desirable.

by him to the museum of the Geological Society. These Cyclas-looking shells are *Estheriæ*.

In his 'History of the Fossil Insects in the Secondary Rocks of England,' 1845, Mr. Brodie gave fuller details of these sections. That of Wainlode (p. 58) is as follows[1]:

		Feet.	Inches.
1.	Black clay	3	0
2.	Hard blue limestone, with *Ostrea*, *Modiola minima*, and other shells	0	4
3.	Yellow shale, with traces of Fucoids	0	10
4.	Grey and blue limestone, with Insect-remains	0	5
5.	Marly clay	5	3
6.	Hard, yellow, nodular limestone, with small shells like *Cyclas* (*Estheriæ*), *Cypris*, *Unio*, Plant-remains (*Naiades*), and some scales of Fishes, varying from 6 in. to 8		
7.	Yellow clay	9	0
8.	Black shale	3	0
9.	Hard, grey stone, with impressions of Fucoids on the upper surface, and with scales and teeth of Fishes (*Gyrolepis*, *Hybodus*, *Acrodus*, *Saurichthys*, *&c.*)	0	1
10.	Black slaty clay	1	6
11.	Pecten-bed. Very hard, brownish, pyritous stone, with Pectens (*Pecten Valoniensis*), and one or two other shells (*Avicula contorta*)	0	4
12.	Black shale	8	0
13.	Bone-bed. Hard, thin, pyritous bed of bones, scales, and teeth of Fishes,[2] associated with a white and yellow sandstone full of casts of *Pullastra arenicola*	0	3
14.	Black shale	2	0
	Green and red marls of the New Red Sandstone.		
		34	8

Specimens of *Estheria minuta*, var. *Brodieana*, from Wainlode Cliff are figured, Pl. II, figs. 12—15; they vie with the specimens of *E. minuta* from Pendock in their good state of preservation.

At page 79 of 'Hist. Fos. Insects,' Mr. Brodie describes the section at Garden Cliff, Westbury, with its "hard, yellow, and grey limestone, often slaty and sandy, with supposed Cyclas," &c.; but we here copy the more detailed section given by Dr. T. Wright, F.G.S., in the 'Quart. Journ. Geol. Soc.,' 1860, vol. xvi, p. 378.

[1] See also 'Quart. Journ. Geol. Soc.,' xvi, p. 379.

[2] The following are the genera of Fishes that occur in the Bone-bed of England and the Continent (see Dr. Wright's paper, 'Quart. Journ. Geol. Soc.,' vol. xvi, p. 388):—*Gyrolepis*, *Hybodus*, *Acrodus*, *Nemacanthus*, *Ceratodus*, and *Saurichthys*.

"Section of the *Avicula-contorta*-beds at Garden Cliff, near Westbury-on-Severn. (The beds are described in descending order.)

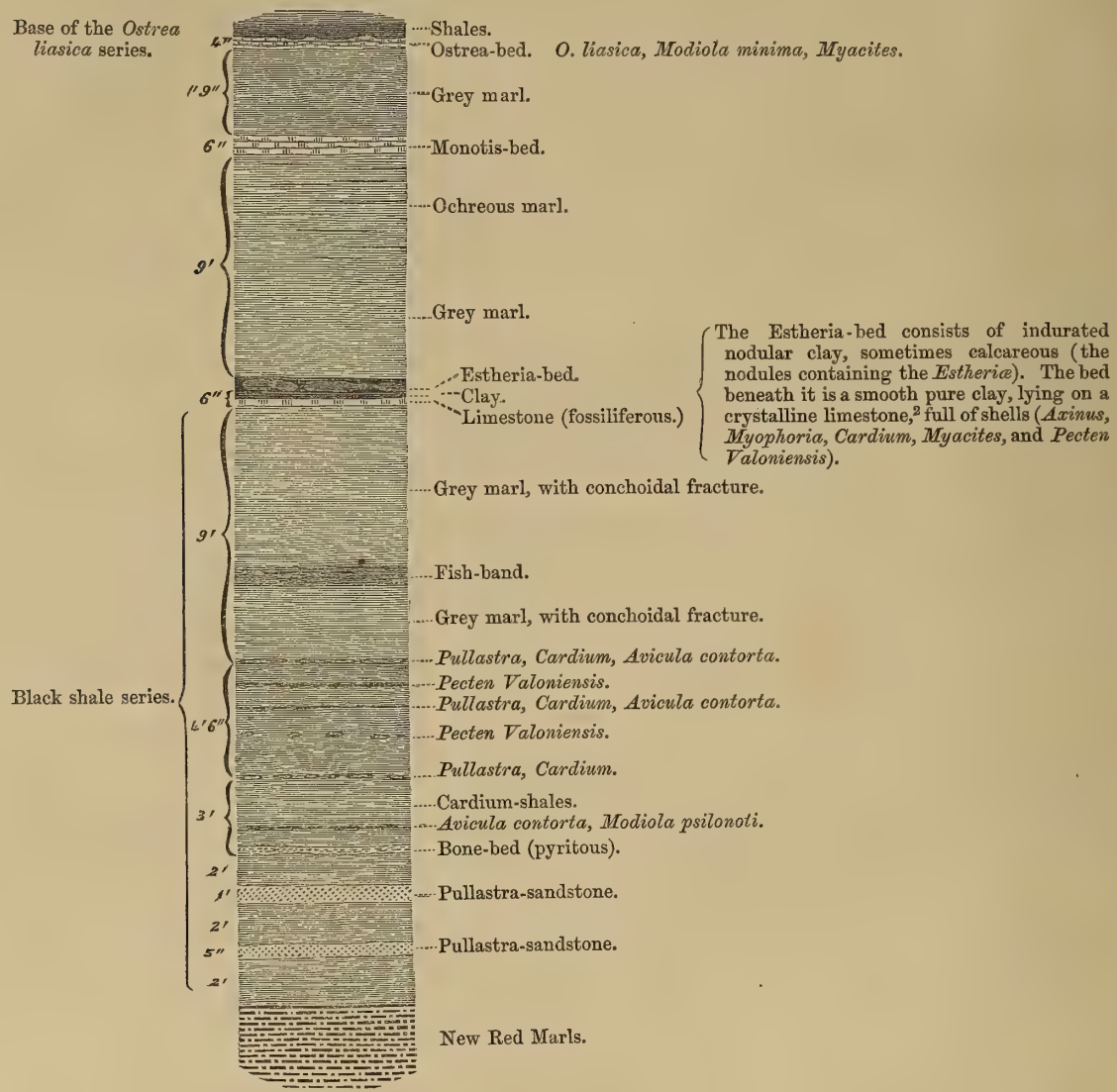
No.	Lithology.	ft.	in.	Organic Remains.
1.	The *Ostrea-bed;* a hard, dark-grey, argillaceous Lias limestone; many shells on the surface	0	4	*Ostrea liasica*, Strickl., *Modiola minima*, Sow., *Cardium*, n. sp. (This bed is one of the lowest of the Ammonites-planorbis-series.)
2.	Greyish clay ....from 1 ft. to	2	0	
3.	The *Monotis-bed;* a cream-coloured, argillaceous fissile limestone (the "Insect-limestone" of Brodie) from 4 in. to	0	8	The Monotis-bed contains *Monotis decussata*, Goldf., in great profusion in the upper laminæ; and in the lower, *Myacites musculoides*, Schl. (?), *Cardium Rhæticum*, Mer., *Modiola minima*, Sow., *Monotis decussata*, and *Ostrea liassica*.
4.	Greyish shaly clay ....from 1 ft. to	2	0	
5.	The *Estheria-bed;* a light-grey nodular limestone, in parts shelly; forming a prominent band in the cliff	1	0	The Estheria-bed contains in some part nests of *Estheria minuta*, Bronn. In the shelly portions I have found *Pecten Valoniensis*, Defr. (Brodie mentions also the occurrence of *Cypridæ*, Plants (*Naiades*), and scales of Fishes in this bed.)
6.	Dark friable shale; containing many fossiliferous seams ....8 ft. to	10	0	Many small compressed *Conchifera*, which have not been determined.
7.	Dark shaly clay; containing many compressed shells	1	0	*Pullastra*.
8.	Dark shale; containing many seams of compressed shells	4	0	
9.	The *Pecten-bed;* a dark argillaceous limestone	0	2	*Pecten Valoniensis*, Defr., numerous and compressed.
10.	Black shales	6	0	Fossils rare; bodies resembling Coprolites.
11.	The *Bone-bed;* a thin band of greyish calcareo-siliceous rock; containing osseous *débris* and much pyrites. A true bone-breccia	0	1	Bones of Saurians and Fishes, teeth of Reptiles, teeth of Fishes, as *Saurichthys*, *Acrodus*, *Hybodus*, and *Ceratodus*, with many Coprolites.
12.	Black shales	2	0	
13.	Dark-grey micaceous sandstone; ripple-marked on the upper surface; forming a prominent bed in the cliff; large slabs lie on the shore ...9 in. to	1	0	*Avicula contorta*, Portl., *Cardium Rhæticum*, and *Pullastra arenicola*, Strickl.
14.	Black shale	2	0	
15.	A band of grit resembling No. 13; containing scales and teeth and much pyrites	0	4	Bones, scales, and teeth of Fishes; *Pullastra arenicola*.
16.	Hard black shale	2	0	Bodies resembling Coprolites.
	Grey marls of the Keuper.			

"The beds are all conformable, and dip to the S.E. at angles varying from 2° to 4°. The Keuper Marls are exposed to the Cliff, with a thickness of above eighty feet. When

this section is lit up by the sun's rays, and seen at a distance of two miles, it has a most beautifully picturesque appearance from the varied colouring of its different beds."

The strata of this section, from No. 2 to No. 16, inclusive, belong to the "Avicula-contorta-series" of Oppel, Wright, and other palæontologists, or to the "Rhætic formation" of Gümbel, C. Moore, and others, and are separated from the Lias above and the Trias below more or less distinctly according to the palæontological views of the several observers.[1]

To R. Etheridge, Esq., F.G.S., of the Geological Survey, I am indebted for the accompanying, still more accurately measured, section and diagram of the interesting strata of Garden Cliff, Westbury.



[1] See Mr. C. Moore's memoir on this formation in the 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 483.

[2] The same as the fossiliferous bed at Beer-Crowcombe, in Somersetshire, described by Mr. C. Moore, 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 486.

In his work on 'Fossil Insects,' at page 82, Mr. Brodie also notices the existence of a band of white stone with "Cyclas?" in the cliff at Aust Passage, on the Severn, about twelve miles from Bristol, and this he refers to the Estherian zone of Westbury and Wainlode, or what he terms the "Cypris-bed." And at page 72 Mr. Brodie mentions that Mr. H. E. Strickland found "the yellow Cypris-limestone with Cyclas," at Dunhamstead, on the line of the Gloucester and Birmingham Railway, near the Droitwich station.[1]

Other sections of the Rhætic beds in Warwickshire and elsewhere are described by Dr. T. Wright in his paper 'On the Lower Lias and Bone-bed,' already referred to. Thus, at pages 386 and 387 we find the following section of Messrs. Greaves and Kirshaw's quarry at Wilmcote, near Stratford-on-Avon:

Beds Nos. 1—20.—Clays, shales, and limestones, belonging to the zone characterised by *Ammonites planorbis*.

	No.	ft.	in.	
Ostrea and Saurian Beds.	21. Dark, hard, stony clay	0	7	"Ruskins." *Plesiosaurus megacephalus*, Stutchb. (Warwick Museum).
	22. Dark-blue limestone and clay	0	9	"Blue Blocks" or "Fire-stone blocks."
	23. Dark clay, laminated	1	0	
	24. Dark greyish limestone	0	4½	"Pendle and Jackets." *Ostrea liasica, Modiola minima*, and *Cardium*.
	25. Hard crystalline limestone	1	2	Fire-stone, top bed.
	26. Hard crystalline limestone			Fire-stone, middle bed.
	27. Hard crystalline limestone			Fire-stone, bottom-bed.
				Bottom of the quarry; shaft sunk below this.
	28. Hard, dark, slaty shale	1	0	
	29. Hard shelly limestone	0	1	"The Guinea-bed." *Avicula, Lima, Ostrea*, &c.
	30. Green clunchy shale	3	0	
Westbury Beds.	31. Fine-grained greenish marl	0	3	Estheria-bed. *Estheria minuta* in clusters.[2]
	32. Blackish shales, not laminated	12	6	
	33. Close, laminated, micaceous, greenish-black shale	1	0	
	34. Closely laminated shale	0	6	
	35. Laminated shale	1	6	Upper Pullastra-bed. *Avicula contorta, Pullastra arenicola*, and *Cardium*.
	36. Hard, close shale, not laminated	2	6	
	37. Dark clay and shale	0	6	
	38. Strong laminated clay, with septaria	1	3	
	39. Clay, with shells	1	8	Pecten-bed. *Pecten Valoniensis*.
	40. Black, hard, laminated clay	4	0	
	41. Pyritic stone, with shells	0	1	Lower Pullastra-bed.
	42. Black clunchy clay	0	8	
	43. Light, soft, brown clay	0	0	

[1] See also 'Proceed. Geol. Soc.,' vol. iii, pp. 315, 587, 732.

[2] Mr. Kirshaw has favoured me with a specimen from this Estheria-bed. It is part of a nodule of grey compact limestone, traversed by a band of *Estheriæ*, both well preserved and in fragments.

At pages 394 and 395 of the same memoir there is the following section taken at Binton, in Warwickshire:

Section of the Zones of *Ammonites planorbis* and *Avicula contorta*, at Binton, Warwickshire.

Beds Nos. 1—36 are thin limestones and clays, 24 feet; with *Ichthyosaurus*, Fishes, *Ammonites planorbis, Lima, Cardium, Ostrea liasica, Modiola minima, Myacites, Avicula, Monotis, Cidaris, Hemipedina*, Insects, and a Fern.

No.		Thickness. ft.	in.	
37.	Thick clay-bed; yellowish-blue; breaking in angular fragments	8	0	[Belonging to the zone of *Avicula contorta*.]
38.	Dark ferruginous clay, with conchoidal fracture	0	4	Estheria-bed. *Estheria minuta.*
39.	Clay			"Clear blue blocks."
40.	Laminated clays	3	0	
41.	Light-coloured sandstone; micaceous	0	1	*Pullastra arenicola*, Strickl.
42.	Brown clay	0	2	
43.	Sandstone; micaceous	0	2	*Pullastra arenicola*, Strickl.
44.	Dark shaly clay	0	6	
45.	Soft sandstone	0	1	
46.	Black clay	0	3	
47.	Ferruginous vein, sand	?		
48.	Grey Keuper marls			

Mr. J. W. Kirshaw, F.G.S., of Warwick, has favoured me with several specimens of *Estheria minuta*, var. *Brodieana* (January 9th, 1862), and with the following note on its occurrence in the district to which he has given much attention.

"The Estheria-bed of the Rhætic formation is very persistent below either the 'White Lias' or the 'Firestone beds,' wherever these occur. There is generally a greenish-grey clunchy marl above and below the bed. I have found this stratum in Warwickshire,—in the railway-cutting north of Stratford; at Ashton-Cantlow; at Wilmcote (see above, page 71); between Wootton Park and Shelfield, S.W. of Henley-in-Arden (whitish, earthy limestone, with well-preserved *Estheriæ*); at Brown's Wood, Moreton-Baggott (compact greyish marlstone, with *Estheriæ* well preserved[1]); at the bottom of the Harbury cutting on the Oxford, Worcester, and Wolverhampton Railway, near Leamington (yellowish-grey, calcareous, laminated sandstone); at the bottom of Ufton Hill; at Long-Itchington; in Worcestershire, at Cracombe, N.W. of Evesham (grey earthy limestone, like

[1] This Estherian rock is much like that found by boring at Wilmcote, but it is browner and less calcareous.

the Estherian bed at Westbury, and a yellowish-grey limestone), and at Hob-Lench.[1]

"Mr. Tomes and I found it also at Barrow, in Leicestershire, and at Penarth, South Wales; and when we were with Mr. Charles Moore at Vallis, near Frome, we found *Estheriæ* in the same relative position." (See below.)

II. *Staffordshire.*—In Staffordshire also this *Estheria* appears to have been met with, according to the following quotation from Dr. T. Wright's paper. (*Loc. cit.*, p. 385)—

"The Sandstone of the Bone-bed has been found, by Mr. H. Howell, of the Geological Survey, at Abbot's Park, near Abbot's-Bromley, Staffordshire, at the base of an outlier of the Lower Lias. In a section which is exposed in the road at Buttermilk Hill, on the northern escarpment of this outlier, Mr. Howell found some beds of impure limestone, above which is a thin bed of micaceous sandstone containing *Pullastra arenicola*, Strickland, and what appear to be *Estheriæ*, all of which are in moulds and casts."

III. *Somersetshire.*—The same variety of *Estheria minuta* has been found by Mr. Charles Moore, F.G.S., of Bath, in some Rhætic beds which he discovered a few years since in the neighbourhood of Frome, Somersetshire. He thus describes the section of the strata referred to ('Quart. Journ. Geol. Soc.,' vol. xvii, p. 497):

"In the Vallis, near Frome, there are quarries worked for the Carboniferous Limestone, some of the beds of which have their upturned edges capped with horizontal Inferior Oolite. In a section near Hapsford Mills I noticed a conglomerate with a few thin intermediate layers of stone and clay. The limestone in this section has a dip of 35° N.W., and is worked to a depth of fifteen feet. Lying upon it there is a band of blue clay, four inches in thickness, which, on close examination, I found to contain a very interesting fauna. Associated with remains of Fishes and Reptiles of the Bone-bed age, it yielded *Avicula contorta, Ostrea interstriata* abundantly, *Pecten Valoniensis*, with other genera never before noticed in beds of this age, such as *Chiton, Pollicipes*, &c. This clay is succeeded by a dense conglomerate of rounded siliceous pebbles, two feet thick, and containing, though rarely, Fish-teeth and scales; another blue clay of four inches succeeds, but without organic remains; then a grey conglomerate, four inches, upon which there are courses of grey or cream-coloured nodular limestone, intermingled with a grey clay, one foot in thickness. In this, organic remains are extremely rare. Specimens of *Estheria*, Insects, and one block containing Plant-remains are all I have obtained. Above the latter are beds of Inferior Oolite, twelve feet in thickness, conglomeratic at their base.

"The interposed beds of conglomerate, stone, and clay between the Inferior Oolite and the Carboniferous Limestone, although but four feet in thickness, may represent in this section the geological eras of the *White Lias*, the *Estheria-beds* of Warwickshire and

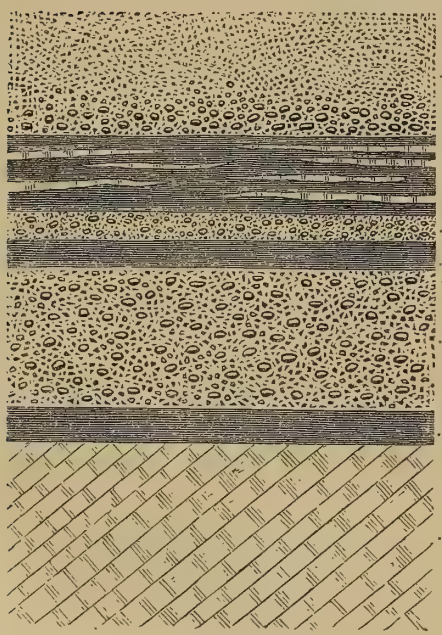
[1] At all these localities the Estheria-bed occurs at the same horizon as it does at Westbury, according to Mr. Etheridge, who has kindly assisted me in examining several specimens collected by Mr. Kirshaw and himself, in Warwickshire, and now in the Museum of the Geological Survey.

Gloucestershire, the *Avicula contorta zone*, and the *Bone-bed;* so that, were the 'White Lias' to be considered to represent a distinct formation, not less than four geological eras would be exhibited in one section of about thirty feet in depth.

"A thin band of conglomerate, one and a half inch thick, of precisely the same aspect, and the same age, is present in the Uphill railway-cutting, near Bristol."

Mr. C. Moore has lent me three specimens containing *Estheria* from the Vallis. One is a fragment of hard calcareous conglomerate, consisting of brecciated limestone (mountain-limestone?), small, oval, rounded pebbles of similar dark-coloured limestone, and a cream-coloured calcareo-argillaceous matrix, in which, besides a cast of *Cardium* (obscure), are some ill-preserved but distinct specimens of *Estheria minuta*, var. *Brodieana*, preserving, in some degree, their convexity. The other two specimens are pieces of a light-grey, laminated, calcareo-argillaceous stratum, slightly micaceous, with minute, dark, vegetable (?) specks, and rare scattered individuals of the same *Estheria*, convex and well preserved (Pl. II, fig. 8, is taken from one of these specimens). These *Estheriæ* from Frome are rather larger than those of Westbury and Wainlode.

Fig. 4.—*Section in the Vallis, near Frome, Somersetshire.*



IV. *Morayshire.*—In the Rhætic formation are included the fossiliferous shales, lying on the "cornstone" and Triassic (?) sandstone, at Linksfield, near Elgin, in Scotland.

In these beds also occurs the same variety of *Estheria minuta* as that which we find in Gloucestershire and near Frome; but it is somewhat larger than those of Wainlode and Westbury, and of a squarer and more symmetrical form; and occasionally it is less strict in its pattern of superficial ornament than is usual in either *Estheria minuta* or the var. *Brodieana*. (See Pl. II, fig. 11, and Pl. V, fig. 10.)

The late Mr. Patrick Duff favoured me (in 1860) with some specimens from his cabinet, collected probably many years ago, which consist of a hardish, greenish-grey, fine-grained, sandy, calcareo-argillaceous shale, crowded with thin, light-brown, and dark-brown *Estheriæ*, preserving but very little of their original convexity. These have here and there a reticulate ornament (such as seen in Pl. II, fig. 10), but often appear to be smooth.

Mr. S. H. Beckles, F.R.S., F.G.S., kindly procured for me, in 1861, a quantity of the Estherian shales, from Linksfield; these are also greenish-grey, calcareo-argillaceous shales, but are soft, contain fewer *Estheriæ* (which are thin, flattened, and of a light-brown colour), and are associated with similar shales full of *Cypridæ*. A few *Estheriæ* are sometimes scattered among the *Cypridæ*. The specimens here have often a boldly reticulate ornament, passing (towards the ventral edge) into short transverse bars (such as seen in the North American *Estheriæ*, Pl. II, fig. 37).

Lastly, Mr. Charles Moore, F.G.S., has lent me some specimens of green clay from Linksfield, crowded with dark-brown, crushed *Estheriæ*, having a distinct reticulate ornament (Pl. II, figs. 9—11).

The Linksfield shales of Morayshire have long been known from the careful description of them published by the late Mr. Patrick Duff, of Elgin, in his 'Sketch of the Geology of Moray,' Elgin, 8vo, 1842.

At first they were collocated with the Wealden or rather the Purbeck beds, by Dr. J. Malcolmson (see Mr. Duff's 'Geol. Moray,' p. 19, and 'Quart. Journ. Geol. Soc.,' vol. xv, pl. xi, fig. 2); Mr. Beckles[1] also, in 1858, was struck with the close lithological resemblance of the Linksfield shales to the Purbeck beds. Prof. Morris has considered these shales to represent a freshwater deposit of the Lower Oolite period (like the Brora beds), as is evident by his referring the Linksfield fossils (in his 'Catal. Brit. Fossils') to the Great Oolite. In 1860 Mr. Charles Moore ('Quarterly Journal Geological Society,' vol. xvi, p. 445) recognised a similarity of appearance between the shales and thin limestone bands at Linksfield and those of the Bone-bed (or Rhætic) series (at the base of the Lias) at Pylle Hill, near Bristol, at Aust Passage and Penarth, on the Severn, and at the Uphill cutting on the Great Western Railway, and more particularly in the presence of beds at Linksfield representing the "White Lias," the "Cotham Marble," the "Bone-bed," and the gypseous clay-bands of the Rhætic formation in the South of England. The fossils also appeared to him to support this correlation. Lastly, the Rev. W. S. Symonds, writing in 1860, refers to "the probable Liassic and Triassic character of the shales at Linksfield" ('Quart. Journ. Geol. Soc.,' vol. xvi, p. 459. See also 'Edinb. New Phil. Journ.,' New Ser., 1860, vol. xiii, p. 99).

[1] My friend Mr. Beckles kindly went to considerable expense (in 1861) to obtain for me a large series of these fossiliferous shales and limestones, especially those rich with *Cypridæ* and *Estheriæ*.

In chapter ii (pages 15—19) of the 'Geology of Moray,' these shales are thus described by Mr. Duff:

"Immediately below the drift of sand and gravel, are found, in the Eastern Division [of Moray], the Lower Purbeck beds of the Weald. These form the uppermost group of the Oolitic series; they are essentially freshwater or estuary: they consist of numerous alternate beds of grey, green, blue, and almost black layers of highly tenacious clay, between which are interposed at intervals double bands of coarse, light-green-coloured limestone, having a plain earthy fracture, which yields, when burned, a yellow powder, like peat-ashes. The uppermost limestone band is covered above by a layer of green clay, and rests on a band of whitish slate-like slabs, which, when split, present septaria of a greenish colour. To these succeed, in the descending order, beds of green and blue clay; next, a second band of limestone, which rests on a bed of dark-coloured shale, containing slabs varying from one to three inches in thickness, of a dark-grey, sparkling, highly crystallized limestone, on the upper surface of which are imbedded numerous bivalve estuary shells; and on the lower surface is a ferruginous crust, in which are found numerous scales, teeth, and spines of extinct species of sharks and pike, and bones, &c., of other animals. Through the substance also of these slabs are found fossils in abundance. The shale which contains these fossiliferous slabs appears to be composed, to the thickness of three feet, of the shelly coverings of a minute crustacean, called *Cypris globosa*, and is a striking instance of the great length of time that must have elapsed ere beds of such extent could have been formed from the exuviæ of myriads of insects whose individual size did not equal the head of a pin. Below this bed of shale are other layers of various coloured clays; the whole resting on the cornstone or limestone bed, belonging to the sandstone formation to be afterwards noticed. But between the cornstone and the Wealden beds, and pervading the surface of the lime-rock, is a bed of reddish clay, or till, four feet thick, interjected, as it were, between the Wealden beds and the cornstone. . . . . The Wealden beds occur at five different localities in the Eastern District [of Moray], viz., 1st, in the bank at the west end of the town of Elgin, on which the House of Maryhill stands. . . . . 2nd, at Linksfield. . . . . 3rd, in a field to the westward of the House of Pitgaveny. . . . . 4th, in a bank on which the ruins of the Castle of Spynie are situated; and 5th, in a field a little westward of Waukmill. . . . . But the most interesting locality is at Linksfield, where a series of beds, forty feet in thickness, has been cut down and removed, in order to get at the limestone below. . . . . The provincial name of these beds is, 'The Cutley Clay.' . . . . . We owe the identification of the Wealden beds of Moray with those of Sussex, to Dr. John Malcolmson, of India."

The fossils of these shales and limestone bands of Linksfield are stated by Mr. Duff to be—

Teeth, scales, and dorsal spines of *Hybodus* (*H. Lawsoni*, Duff). Teeth and scales

of *Lepidotus;* and a nearly perfect *Lepidotus* (?).[1] Teeth of *Acrodus.* Teeth of *Sphenonchus.*[2] Femur of a Chelonian animal. Vertebræ of *Plesiosaurus subconcavus,* Duff. Saurian teeth. *Mytilus, Unio, Astarte, Cyclas media, C. membranacea, Planorbis, Paludina,* and *Cypris globosa.* Fossil wood and lignite.

The late Mr. Duff most obligingly favoured me (in 1860) with specimens of the *Estheria* from Linksfield, and in February, 1861, replied most courteously to my inquiries respecting these fossils; and I learned from him that they used to be termed "Cyclas?" and "Operculum?"; and that they occur abundantly in a greenish-grey, sandy shale, rather flattened, and lying horizontally, some of them with the two valves open, and in their natural position.

The section taken at Linksfield by Mr. C. Moore, in 1860 ('Quart. Journ. Geol. Soc.,' vol. xvi, p. 446), is as follows:

	ft.	in.
1. The till or drift.		
2. Green clay. *Cypris* (rather sparingly). Teeth of *Hybodus,* and scales of *Lepidotus*	1	6
3. Grey stone. Small *Modiola*	5	0
4. Blue, variegated, and green clay. *Cypris* (rare). *Hybodus. Lepidotus*	1	6
5. Stone	1	8
6. Green clay. *Cypris. Estheria. Lepidotus, &c.*	0	10
7. Stone	0	10
8. Dark clay. *Cypris. Lepidotus. Hybodus*	0	10
9. Stone (="Bone-bed"). Teeth and spines of *Hybodus minor.* Teeth, jaws, and scales of *Lepidotus. Sphenonchus Martini,* Ag. Teeth and vertebræ of *Plesiosaurus,* &c. Small Univalve and Bivalve shells. Remains of Plants	0	3
10. Blue clay. *Cypris,* abundant. Fish-remains, rare	4	0
11. Stone	1	4
12. Green marl (*Estheriæ* occurs in some of these lower beds)	0	9
13. Stone	0	10
14. Green marl	2	10
15. Stone	0	10
16. Green marl	2	0
17. Stone	0	8
18. Green marl	0	5
19. Boulder-clay	5	0
20. Cornstone	12	0
21. Reptiliferous Sandstones (?).		

Habitat of E. minuta, *var.* Brodieana.—In Gloucestershire, Worcestershire, and Warwickshire, the Rhætic *Estheria* occurs along a certain zone immediately above a stratum full of marine shells, which, like others belonging to this Rhætic stage, appear to be dwarfed, as if they had been the inhabitants of an unfavorable locality, or lived in sea-water under the influence of large freshwater affluents. In the Estheria-bed itself no marine shells are found. Fragments of terrestrial plants in the associated beds indicate the near proximity of the land to the waters in which these deposits were formed. Here,

[1] In Morris's 'Cat. Brit. Foss.,' 2d edit., by a misprint, "Linksfield, N.B.," is misplaced against "*L. pectinatus,*" instead of against "*L. minor* (?)."

[2] *Sphenonchus Martini,* from Linksfield, Agass., vol. iii, p. 203, t. 22*a*, figs. 15—17, is the "frontal spine" of *Hybodus,* according to Messrs. Charlesworth and Ogilby, 'Magaz. Nat. Hist.,' 1839, new ser., vol. iii, pp. 245 and 280.

as in the Keuper, we may suppose that the *Estheriæ* flourished in brackish, if not in fresh, water, at intervals when the saltness of the sea was more or less reduced by the land-waters.

The absence of *Estheriæ* in the Rhætic beds (or *Avicula contorta* zone) of Germany is coincident, apparently, with their more decidedly marine character; and so also the apparent absence of *Estheriæ* in the Triassic beds of the Alps, with their many fossiliferous strata, may be due to more constant marine conditions having obtained during the Triassic period in that area than in the Western European region.

7. Estheria Mangaliensis, spec. nov. Pl. II, figs. 16—23.

Estheria, *Hislop.* Quart. Journ. Geol. Soc., vol. x, p. 472; vol. xi, p. 371; vol. xvii, pp. 347, 353.
— *Jones.* Ibid., vol. xii, p. 377.

	Inch.		Inch.		Inch.
Height	$\frac{1}{12}$		$\frac{9}{12}$	less than	$\frac{2}{12}$
Length, less than	$\frac{1}{12}$		$\frac{4}{12}$	,,	$\frac{9}{12}$
Proportion	$1\frac{1}{4} : 2$		$1 : 1+$		$1 : 1\frac{1}{2}-$

Carapace-valves usually broadly subovate (fig. 16), but varying from subtriangular (fig. 20) to suboblong (fig. 21), according to age, sex (?), and state of preservation.

In fig. 20 the anterior extremity is truncate, advancing but little beyond the umbo; but usually it curves out boldly from beneath the umbo, not unfrequently with as full a curvature as that of the posterior margin (figs. 21, 23); normally, however, the valve appears to be somewhat narrower in front than behind (figs. 16, 22). The hinge-line, terminated in front by the umbo, is well marked; in the majority of specimens it is equal to rather more than half the length of the valve (figs. 16, 21); but in others it is little more than a third (figs. 20, 23).

Ridges about fifteen; but in adults they are crowded in increasing numbers towards the ventral border, and become merely the overlapping flat edges of the periodical layers of the carapace; this is well seen where the growth has been irregular, owing to some local accident (fig. 19). The interspaces are broad and smooth, presenting here and there an obscurely hexagonal reticulation of small meshes (figs. 17, 18).

A remarkable similarity exists between this fossil form found at Mángali and a recent *Estheria*, living in the pools near Jerusalem, figured and described by Dr. Baird as *E. Gihoni* ('Annal. Nat. Hist.,' ser. 3, vol. iv, p. 281, pl. v, fig. 1). The valves of the latter, however, have fewer ridges and wider interspaces; and its ornament is a far bolder reticulation than that exhibited by the fossil; were *E. Gihoni* fossilized, however, it would be with difficulty distinguished from *E. Mangaliensis*.[1]

At Mángali, in Central India, about sixty miles south of Nágpur, the Rev. Messrs.

[1] In the 'Memoirs of the Geological Survey of India,' vol. iii, p. 197, Dr. Oldham has by mistake stated that Mr. Hislop's specimens of *Estheriæ* from Mángali were identified by me with *E. minuta*.

S. Hislop and R. Hunter discovered in 1853 a fossiliferous sandstone, which is described[1] in the 'Quart. Journ. Geol. Soc.,' vol. xi, p. 370, and vol. xvii, p. 347. This sandstone extends between Mángali and Mesá, near Chickni; it is fine-grained, red in colour, somewhat argillaceous and micaceous, thin-bedded, and about fifteen feet thick, lying between an upper and a lower sandstone, both of them coarser in texture, lighter in colour, and thick-bedded. The red laminated sandstone contains Plant-remains,[2] ganoid scales and small jaws of Fishes, Labyrinthodont remains (*Brachiops laticeps*, Owen), and wide-spread, thin layers of *Estheriæ*.

From the evidence of the organic remains found in this red sandstone at Mángali and Mesá, Mr. Hislop is inclined to consider it as of the same age as the plant-bearing sandstone of Nágpur, and the coal-shales of Umret and of the south base of the Mahádewa Hills, and to refer the whole to the Upper Triassic Formation (Letter, July 19th, 1861); Messrs. Blanford and Theobald, however, of the Geological Survey of India, seem disposed to place the Mángali beds above the plant-sandstone and coal; and, as they consider the former to be probably of Permian age, the two latter they regard as at least of that age ('Quart. Journ. Geol. Soc.,' vol. xvii, pp. 347; and 'Mem. Geol. Surv. India,' vol. i, part 1, p. 82).

In a comprehensive memoir 'On the Probable Relationships of the Strata in Central and North-Eastern India' ('Memoirs Geol. Surv. India,' vol. ii, part 2, 1860, p. 333), Dr. Oldham states that "the probability would seem to be that our 'Damuda System' (true Damuda Series of the accompanying table) belongs to some portion of the Upper Palæozoic division of European geological sequence, or to the lowermost portion of the Mesozoic division. In fact, we may possibly hereafter find that it will represent that great interval indicated by the marked separation and great break between the two series in other countries."

Of Mr. Hislop's group "B" (see p. 80), Dr. Oldham would certainly take the Umret coal-series to belong to the Lower Damuda Series; he does not think that the Kotá beds of fish-bearing shales and limestone are of the same age as these, but higher in the geologic scale, in which opinion Mr. Hislop coincides. (Letter of July 19th, 1861; and 'Quart. Journ. Geol. Soc.,' vol. xviii, p. 36.)

To show at a glance the present state of opinion as to the relationships of the Indian strata above referred to, I insert a synoptical table, comprising the classifications adopted by Dr. Carter, by the Rev. Messrs. Hislop and Hunter, and by Dr. Oldham and his colleagues of the Geological Survey of India.

[1] For the particulars of the geology of the Nágpur district, in Central India, where these sandstones and other strata of great interest occur, see Mr. Hislop's memoirs in the 'Journ. Asiat. Soc. Bombay,' vol. v, pp. 58 and 148; vol. xxiv, p. 347; and in the 'Quart. Journ. Geol. Soc.,' vol. x, p. 472; vol. xi, pp. 345 and 555; and vol. xvii, p. 346, &c.

[2] *Knorria* (?) or the stem of a Conifer; *Stigmaria* (?) or the rhizome of a Fern; *Phyllotheca* (?), stems, &c.

Synoptical Table of the Lower Mesozoic and the Palæozoic Formations of Central India.

Dr. Carter.	Messrs. S. Hislop and R. Hunter.				Geological Survey of India.
I. Panná Sandstone.	Upper Sandstone Series.	Group A.	Near Nágpur, 25 feet thick; at the Mahádewa Hills, 2000 feet.	6th.	Mahádewa[1] and Lameta Series.
II. Kattrá Shales.	Laminated Series.	Groups B and C[2]	Fish-shales, limestone, and *Estheria-shales* of Kotá.	5th.	Upper Damúda and Rájmahal Series.
			Coal-shales of Umret.		
			Plant-sandstones of Nágpur.		Panchét Series. (*Estheria.*)
			Estheria-sandstone of Mángali, with *Reptile* and *Fishes.*	4th.	True Damúda Series. (Coal-bearing.) The upper beds form the Rániganj Group. (*Reptiles.*)
			Argillaceous shales of Korhádi; track-marked.		Lower Damúda (of Medlicot) or Bárákar Series.
			Ceratodus-clay of Máledi.	3rd.	Talcheer Series. Sandstone, Conglomerate, &c., without Coal.
		Group D.	Limestone: Near Nágpur, about 100 feet thick.	2nd.	Vindyhan Series. Bundair Group. Rewah Group. Kymore Group. — Sandstone and Shale, without Coal.
			Limestone: In Moodelaity, 310 feet thick.		
III. Tará Sandstone.	Lower Sandstone Series.		Moodelaity and Bundelcund.	1st.	Sub-Kymore Series. Semri Group. Tirhowan Limestone. — Metamorphic (?) and unfossiliferous.
					Bijawur Group.

[1] Probably of Upper Cretaceous age, according to Mr. Hislop, 'Bombay Asiat. Soc. Journ.,' vol. vi, No. 21, 1861, p. 200.

[2] The arrangement of these beds has been modified in accordance with communications lately received from Mr. Hislop; but it is not yet regarded as perfect. See also Mr. Hislop's latest memoir in the 'Journ. Bombay Asiat. Soc.,' vol. vi, p. 194, &c.

Thus divided as the opinions of the Indian geologists are respecting the age of these plant-bearing and Estherian strata of Central India, I venture still to regard them as belonging to the 'Rhætic Formation,' in accordance with some suggestions which I made in 1856 ('Quart. Journ. Geol. Soc.,' vol. xii, p. 376).

Habitat.—The absence of marine-remains in the Plant-bearing and Reptiliferous sandstone of Mángali goes far to indicate the freshwater habitat of the *Estheriæ* so abundant in one of its beds.

Dr. T. Oldham, F.R.S., the Superintendent of the Geological Survey of India, has kindly and promptly forwarded to me a piece of the Estheria-bed not long since discovered by Mr. W. T. Blanford, near Panchét (pronounced Pa'cheet), five miles south of the Damuda River, and 110 miles north-west of Calcutta, in Bengal. (See 'Memoirs Geol. Survey, India,' vol. iii, part 1, pp. 132—137, and p. 197; also 'Journ. Bombay, Asiat. Soc.,' vol. vi, p. 203.) The rock is a fine-grained, yellowish-grey, sandy, micaceous shale. The *Estheriæ* are of small size, lie closely together on one plane, and, retaining no shell, or only an excessively fine film, are represented by obscure casts and moulds, of a darker tint than the matrix. A few fragmentary plant-remains lie on the same bed-plane.

The general size of the specimens is as follows—

Height ..... $\frac{3}{12}$ inch; Length..... $\frac{1\frac{1}{2}}{12}$ inch; Proportion ..... 1 : $1\frac{1}{2}$+

In shape the valves appear to be subovate, with a tendency to become oblong (like fig. 21, in Pl. II). The concentric ridges are delicate and apparently numerous (about 20); but no ornament of the interspaces can be discerned even on the few valves that retain a film of shelly matter.

Altogether, judging from the materials before me, I have no grounds for deciding whether this *Estheria* from Panchét is or is not the same as that from Mángali, some of the smaller forms of which it seems to resemble, as already suggested by Hislop and Oldham ('Journ. Bombay Asiat. Soc.,' vol. vi, p. 203).

8. Estheria Kotahensis, Spec. Nov. Pl. II, figs. 24, 25.

Estheria, *Hislop.* Quart. Journ. Geol. Soc., vol. xvii, p. 348.; Journ. Bombay Asiat. Soc., vol. vi, p. 201.

Height, more than $\frac{1\frac{3}{4}}{12}$ inch
Length..... $\frac{1\frac{4}{4}}{12}$ „ } Proportion 1 to $1\frac{1}{4}$+

Estheriæ have been found by the Rev. Mr. Hislop in a light-coloured shale at Kotá

(or Kotah), on the Pranhítá, together with ganoid Fishes (*Lepidotus Deccanensis*), *Cypridæ*,[1] Insects, *Unio* (?) and some Plant-remains.

These *Estheriæ* occur as very thin, light-brown, compressed, and often ragged carapace-valves, in a whitish calcareous shale, thickly crowded on the thin laminæ, and associated with a layer of *Cypridæ* (see Appendix, Pl. V, fig. 25), and minute, straight, black, fibrous lines, probably of vegetable origin, lying horizontally in every direction throughout the shale. Small fragments of a Fern (*Glossopteris* ?) also occur in the shale. The *Estheriæ* are much smaller than the generality of those in the sandstone of Mángali (figs. 16 and 20), but have a round-ended oblong outline not unlike that of some individuals from this locality[2] (compare figs. 21 and 24). The surface of the valves exhibits, under the microscope, about ten delicate, concentric ridges, separated by interspaces usually smooth, or traversed by faint lines parallel to the ridges, but occasionally ornamented towards the ventral border by a pattern consisting of slight, vertical, anastomosing wrinkles, with accompanying rows of minute pits (fig. 25, magn. 100 diam.) No such ornament as this is traceable in any of our numerous individuals of *E. Mangaliensis*, nor do the latter show the faint concentric striæ of the interspaces, but either a blank smoothness or an obscurely hexagonal reticulation (figs. 17, 18). Although *Estheriæ* having a reticulate ornament do sometimes take on a transversely barred or wrinkled pattern also (as in *E. ovata, E. Murchisoniæ, E. minuta* var. *Brodieana* (of Linksfield), &c. yet the latter may be the essential and sole ornament of a species (as in *E. elliptica*); and this may be the case here.

In its different style of ornament, therefore, as well as in its fewer ridges, squarer outline, smaller size, and thinner valves, the *Estheria* from Kotá differs considerably from *E. Mangaliensis*.

The Fish-shale, limestone, and Estherian shale of Kotá[3] are regarded by Mr. Hislop as of Lower Jurassic (Liassic) age, and as lying above a sandstone, with plant-remains, probably equivalent to the plant-bearing sandstone of Nágpur (Letter, July 19th, 1861), and the latter is on the geological horizon of the "Damuda group," of Bengal (See the Table, page 80).

[1] *Cypridæ* are also found (generally compressed) in the bituminous shales of Kotá, in which *Lepidotus Deccanensis, L. longiceps,* and *L. breviceps* occur, with Plant-stems and *Glossopteris* (?). In the limestone at Kotá, Fish-remains (*Æchmodus Egertoni* and *Lepidotus*) occur; also Teleosaurian remains, *Sphenopteris*, &c., 'Bombay Asiat. Soc. Journ.,' vol. vi, p. 201.

[2] Hence I was at first led to regard the two forms as probably belonging to the same species. Op. cit., pp. 348 and 353.

[3] For notices of the Fish-shales and limestone of Kotá, see 'Quart. Journ. Geol. Soc.,' vol. vii, p. 272; viii, p. 231; ix, p. 351; x, p. 371; and xvii, p. 36; also 'Journ. Bombay Asiat. Soc.,' vol. vi, p. 201.

The following is the section at Kotá, on the Pranhítá.

Iron-banded sandstone of the neighbouring hills, 50—500 feet and upwards in height, covered by conglomerate.

Ft.	in.		Ft.	in.
		Regur or cotton-soil } Superficial deposits	15	6
		Clay ..... }	1	0
9	0	Limestone	9	1
6	0	Bituminous shale	0	0¾
		Argillaceous limestone	1	0
		Bituminous shale	0	4
		Fibrous carbonate of lime, impure limestone, and blue clay-rock	0	8
		Bituminous shale	2	1
		Impure limestone	1	9
8	0	Laminated sandstone, blue clay, and shale	8	0¾
11	8	Bituminous shale	1	6
		Fibrous carbonate of lime	0	1
		Bituminous shale	1	3½
		Impure limestone	5	3¼
		Black clay, containing sand	3	6
23	0	Limestone	23	0
25	0	Blue clay.....	7	6
		Limestone	2	0
		Shale and clay ... } (= Green Shales of Korhadi?)	1	9
		Limestone	1	8
		Clay and shale.....	12	0
27	0	Red clay (= Red Clays of Korhadi?)	27	0
		Limestone.		
		Argillaceous sandstone (at Sironchá or Chiranjá, six miles down the river) [= the Silewada plant-sandstone, near Nágpur = Damuda group of Bengal].		

Mr. Hislop has also obtained *Estheriæ* similar to those of Kotá from Kátanapali, about fifteen miles north of Kotá. "Here the argillaceous limestone is about eight feet deep, thick-bedded above, more fissile below; and still lower down passing into white laminated strata, as at Kotá. The slaty limestone abounds with scales of *Lepidotus*, and the underlying white shale with *Estheria*." ('Bombay Asiatic Soc. Journ.,' 1862, vol. vi, p. 201.)

I may here mention that in the seventh volume of D'Archiac's 'Histoire des Progrès de Géologie' (p. 624, &c.), the reader will find a *résumé* of all that was known about the "Jurassic Freshwater Basin of Central India" down to the date of that volume.

Habitat.—None of the organic remains yielded by the Kotá beds above referred to have marine characters, if we except the Lepidoid Fishes as doubtful evidence. The *Cypridæ* associated here with the *Estheriæ* are such as live in fresh water at the present day. (See Appendix.)

9. Estheria ovata, *Lea*, sp. Plate II, figs. 26—38.

Posidonomya minuta (*Bronn*), *W. B. Rogers.* Proc. Acad. Nat. Sc. Philad., 1843, vol. i, p. 249; Posidonia, sp.? Proc. Boston Soc. Nat. Hist., 1854, vol. v, p. 14.

— (?), *Lyell.* Quart. Journ. Geol. Soc., 1847, vol. iii, p. 274, fig. 6.

Posidonia ovata, *Lea.* Proc. Acad. Nat. Sc. Philad, 1856, vol. viii, p. 77.

— parva, *Lea.* Ibid.

— ovalis, *Emmons.* Geol. Rep. North Carolina, 1856, p. 323, fig. W., 1 and 2; Amer. Geol., part VI, 1857, p. 40, fig. 12; Manual Geol., 2nd edit., 1860, p. 191, fig. 166, 3.

— multicostata, *Emmons.* Geol. Rep. N. Carolina, 1856, p. 337, fig. X; Amer. Geol., part VI, 1857, p. 134, fig. 103; Manual of Geol., 2nd edit., 1860, p. 191, fig. 166, 4.

— triangularis, *Emmons.* Geol. Rep. N. Carolina, p. 338, fig. V; Amer. Geol., part VI, p. 134, fig. 104.

	Inch.	Inch.	Inch.	Inch.	Inch.
Height,	$\frac{3}{12}$	$\frac{1}{12}$	less than $\frac{3}{12}$	more than $\frac{2}{12}$	more than $\frac{2\frac{1}{2}}{12}$
Length,	$\frac{1}{12}$	$\frac{1\frac{1}{2}}{12}$	„ $\frac{4}{12}$	less than $\frac{3}{12}$	less than $\frac{4}{12}$
Proportion	1 : $1\frac{1}{4}$	1 : $1\frac{1}{2}$	1 : $1\frac{1}{4}$+	1 : $1\frac{1}{3}$+	1 : $1\frac{1}{2}$—

Carapace-valves broadly subovate, almost semicircular; the straight dorsal line reaches across the valve, the extremities curving suddenly downwards; the postero-dorsal angle being the sharper of the two. The front and posterior margins are nearly equally rounded, but the valve is usually deepest at the anterior third, in a line with the umbo; the well-curved ventral border being rather more oblique posteriorly than anteriorly. The concentric ridges are about fifteen in fig. 26; about twenty-eight in fig. 27; and much more numerous in fig. 28. In fig. 27 we see the gradual crowding of minor concentric ridges towards the ventral border in an adult specimen, and in fig. 28 we have an individual in which, owing to some peculiarity of growth, the ridges are too numerous to be very distinct, and are unaccompanied with any ornament of the interspaces (figs. 29, 30). In other specimens we find, besides blank surfaces (fig. 31), modifications of a reticulate ornament on the interspaces (figs. 32—36), with occasionally a barred or transversely wrinkled pattern (figs. 37, 38). Fig. 31 is a set of narrow interspaces, smooth and without ornament. Fig. 32 shows how a smooth surface may mask the reticulate structure. Figs. 33, 34, 35, and 36 are reticulate interspaces, the meshes being of various sizes and arranged either longitudinally, diagonally, or vertically. In the first case the walls of the meshes would strengthen, if not give rise to, minor concentric striæ; in the last case they may give rise to the bar-ornament, such as is seen in fig. 37. The obliquity of the meshes in fig. 35 may be due to pressure. Fig. 38 seems to show narrow interspaces bounded by thick ridges and crossed by short, thick bars.

For most of these illustrations[1] we have had recourse to specimens from Pennsylvania, Richmond, and Dan River (from Prof. W. B. Rogers' collection), which evidently belong to the same species. These specimens are—

1. From Pennsylvania. Black shale. *Estheriæ* excessively crowded in horizontal layers.
2. From Prince Edward, near Richmond, Virginia. Black shale, with conchoidal fracture, fine-grained. *Estheriæ* tolerably well preserved, but crumpled.
3. From Dan River, North Carolina. Black, laminated shale, obliquely crushed. *Estheriæ* very thin.

Another specimen (from which figs. 28—30 have been taken) is a hard, dark-grey, stony shale, containing a few scattered *Estheriæ* and a fragment of *Equisetites*, brought from Hardin's pit, Richmond, Virginia, by Sir C. Lyell.

As in India so in North America there are fossiliferous and coal-bearing shales and sandstones, the geological age of which is far from being exactly known; these are the plant-bearing beds of Eastern Virginia and North Carolina, with the Estherian shales of the same States and of Pennsylvania, usually known as the Middle and Lower Secondary, or Lower Mesozoic, coal and sandstones of the Atlantic slope. I propose to refer these interesting strata to the *Rhætic* formation while treating of their fossil *Estheriæ*.

In 1843, Prof. W. B. Rogers discovered in Prince Edward County, Virginia, a little fossil which he referred to the European *Posidonomya minuta* ('Proceed. Acad. Nat. Science, Philadelphia,' vol. i, p. 249); and in 1854 ('Proceed. Boston Soc. Nat. Hist.,' 1856, vol. v, p. 14), in treating of the close relationship of the several tracts of the "Middle Secondary Rocks" of North Carolina, Virginia, Pennsylvania, and Massachusetts, and of their probable Jurassic age, he again alluded to this little fossil, but pointed out that both it and another form associated with it "differ in proportion from the *P. minuta* of the European Trias." According to Prof. W. B. Rogers, the "Posidoniæ" of North Carolina (Dan River) "were noticed as early as 1839, by Dr. G. W. Boyd, while on the Virginia Geological Survey," 'Proc. Boston Soc. N. H.,' vol. v, p. 16.

In 1847, Sir. C. Lyell described and figured two apparently well-conditioned *Estheriæ* from the Mesozoic coal-shale of Richmond, Virginia, 'Quart. Journ. Geol. Soc.,' vol. iii, p. 274 (fig. 6); but unfortunately the specimens cannot now be found.[2] The woodcut, though good, does not furnish sufficiently exact evidence of the superficial sculpturing of the shell to enable me to compare it satisfactorily with my own material, though fig. 28 supplies its place to some extent. In this paper Sir C. Lyell stated (p. 275) that he shared Mr. Morris's doubts as to whether the "Posidonomyæ" from Richmond, as well

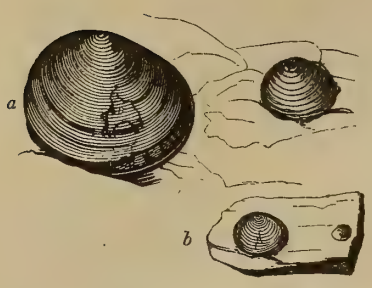
[1] Since these illustrations were drawn and the accompanying text placed in the printer's hands, I have received through Mr. C. Wheatley's liberal kindness a large collection of the Estherian and Cypridiferous shales from Phœnixville; and some notes on these will be appended in the sequel.

[2] These *Estheriæ* are also figured in Lyell's 'Manual of Geology,' 5th edit., p. 332, fig. 422, *a*, *b*.

as the "Posidonomya minuta," may not be allied to *Cypris* rather than to any genus of the Mollusca.

The larger form figured by Lyell (fig. 6 *a*, here copied as fig. 5 *a*) is stated to resemble *Cyclas* in outline; oval and inequilateral; $\frac{6}{20}$ths inch in diameter. It was from Hardin's pit, north of Blackheath, near Richmond, Eastern Virginia.

Fig. 5.



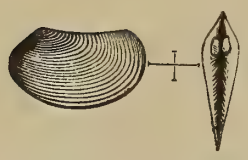
Estheria ovata, *from Richmond. Magnified and of natural size. After Lyell.*

The smaller one (fig. 6 *b*, here copied as fig. 5 *b*), $\frac{2}{20}$ths inch in diameter, is described as being more convex than the other; "resembles a young *Astarte*, but may perhaps be the young of the preceding." From Hardin's pit, and also from Creek mines, south of Blackheath, Virginia.

The same fossils were found at the Deep-run pits, at the northern extremity of the coal-field. "They occur in such immense numbers (at Blackheath) as to divide the shale, like plates of mica, into very thin laminæ. Every fresh surface exhibits a layer of them."

In 1856 Dr. I. Lea read before the Academy of Natural Sciences of Philadelphia,[1] some notes on the "New Red Sandstone Formation of Pennsylvania," and stated that in the greenish and blackish shales near Phœnixville, on the Schuylkill, he found two forms of "Posidonia" (*Estheria*) both differing apparently from those figured by Sir C. Lyell; and he named them the *P. ovata* and *P. parva*, "the first being about $\frac{7}{20}$ths of an inch in transverse diameter; the latter more rotund, and about $\frac{3}{20}$ths of an inch in transverse diameter."

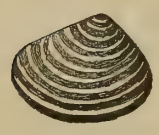
Fig. 6.



Estheria ovata (P. multicostata, *Emmons*), *from North Carolina, magnified. After Emmons.*

Prof. E. Emmons in his 'Geolog. Report of North Carolina,' 1856,[2] p. 337, describes and figures two forms of *Estheria* as *Posidonia multicostata* and *P. triangularis* from the upper portion of the Deep River series in Chatham Co., North Carolina. According to Mr. Conrad,[3] the former of these "had previously been indicated by Mr. Lea under the name of *P. ovata* from specimens obtained at Phœnixville; and probably the latter was also indicated under the name of *P. parva* from smaller specimens than those presented this evening, but likewise obtained from the same locality."

Fig. 7.



Estheria ovata (P. triangularis, *Emmons*), *from North Carolina, magnified. After Emmons.*

The two *Estheriæ* above alluded to are figured and described

[1] 'Proceed.,' vol. viii, p. 77.

[2] In Silliman's 'Americ. Journ. Sc.,' new series, vol. xxiv, p. 427, is a notice of Emmons's 'Geological Report of the Midland Counties of North Carolina,' 1856, with remarks by Professor O. Heer on the Plants noticed in it.

[3] 'Proceed. Acad. Nat. Sciences Philadelphia,' for 1857, p. 150.

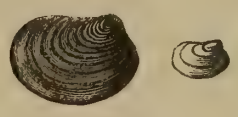
by Prof. E. Emmons in his 'Geol. Report of North Carolina,' 1856, pp. 337, 338, and in his 'American Geology,' part VI, 1857, p. 134. They are from the upper part of the Deep River series (referred by him to the Upper Trias), and occur abundantly six or seven miles south of McInvess.

E. multicostata[1] (here copied as fig. 6), $\frac{5}{20}$ths inch in length, is described as being oval, hinge-line nearly straight; ribs fine, about twenty; similar to an *Edmondia* in shape. ('Geol. Report,' 1856, p. 337, fig. 10.)

E. triangularis (no indication of size given) has the triangular form of *Astarte* (copied here as fig. 7); shell thin; ribs strong and distant, with concave grooves between. ('Geol. Report,' 1856, p. 338, fig. 5.) These occur in company "near the top of the upper red sandstone and marls (Keuper), about seven miles south of Egypt. In these upper beds there are *Cyprides* also, which are quite numerous upon certain soft red layers."

In his 'American Geology,' part VI, 1857, p. 40, Prof. E. Emmons, treating of the animal remains from the shales of the Chatham Series (referred by him to the Lower Permian formation), describes an *Estheria* under the name of *Posidonia ovalis* (previously noticed by him in his 'Geological Report on North Carolina,' 1856[2]), and illustrates it by a woodcut (fig. 12, copied here as fig. 8). It is $\frac{6}{20}$ths of an inch long, thin-shelled, ovate.[3] He says (p. 41) "It is very common. It extends through the series of slates, but I have not observed it in the green magnesian marls. It is also common in the shales of the Richmond basin. Sir Charles Lyell has figured much larger kinds than any which I have seen either in the Deep or Dan River coal-fields." Two or three other little bivalve shells, possibly *Estheriæ*, are also alluded to in the same page; and one of them is figured (fig. 13).

Fig. 8.



Estheria ovata (P. ovalis, *Emmons*), *from North Carolina, magnified, and of natural size. After Emmons.*

To illustrate the geological position of these North America *Estheriæ*, I subjoin an account of the strata of some of the several basins of shale and sandstone, which belong to the same geological horizon as the bituminous formation of Eastern Virginia. These extend in three parallel, unequal, interrupted tracts or belts for nearly 700 miles; from Stony Point along the Hudson River to South Carolina, on the eastern border of the Appalachian or Alleghany mountains.[4]

[1] Figured also in Emmons's 'Manual of Geology,' 2nd edition, 1860, p. 191, fig. 166, 4.

[2] It is again figured in Emmons's 'Manual of Geology,' 2nd edit., 1860, p. 191, fig. 166, 3.

[3] It is figured also in this report (W. 1 and 2); and, referring it to the Mollusca, Prof. Emmons here says (p. 323) that it is the only one of the class hitherto observed in the "Chatham formation." It occurs in the "Black slates," and materially differs, according to Prof. Emmons, from that of the Upper Red Sandstone.

[4] A useful *résumé* of the history of the researches into the geology of these tracts, and of the supposed relationship of this strata, is given by Dr. I. Lea in the 'Journ. Acad. Nat. Sciences Philadelphia,' new

1. The most northern extension of the shales and sandstones under notice is exhibited in Massachusetts and Connecticut; here sandstone appears to predominate, and the well-known fossil Foot-prints of Connecticut are found in some of the beds. Fish-remains and fragments of plants have also been found; but *Estheriæ* have not been observed.

2. The second great area stretches from New Jersey, through Pennsylvania and Maryland, into Northern Virginia. In New Jersey the series consists of—1. (Uppermost) Calcareous variegated conglomerate (with Reptilian remains), and dark-red pebbly sandstone. 2. Brick-red sandstone and shales (with Footprints), and bituminous shales (with Fish-remains). Beds of coarse grey sandstone occur in the lower part of this series. *Estheriæ* have not been met with.

In Pennsylvania the following is the general order of these strata. 1. (Uppermost) Conglomerate, calcareous at places. 2. Red shale and sandstone. 3. Red sandstone and coarse yellowish conglomerates. 4. Red shale and brownish sandstone. 5. Pinkish sandstone and shale. 6. Reddish sandstone and conglomerate (locally calcareous). Prof. H. D. Rogers (whose works supply the above information for New Jersey and Pennsylvania), writing of the Pennsylvanian series,[1] says that it consists essentially of reddish-brown shales and clay, and argillaceous sandstone, in intimate alternations, but locally differing in proportions and distribution. The upper and lower parts of the series are more sandy, and have conglomerates in them, which are locally calcareous. In the middle and upper portions there are sometimes found dark-grey and blue shales, containing carbonaceous matter and some seams of lignite. A detailed section of red and bituminous shales (containing *Estheriæ* Plants, and other fossils), with sandstone, and other deposits,

series, vol. ii, part 3, 1852; and in 1858, he again gave a review of the subject in the 'Proceed. Acad. Nat. Sc. Phil.,' for 1858, p. 90; but the more exact details, and still later information, must be learnt from the works of the Brothers Rogers, Emmons, and others. D'Archiac's 'Hist. Progrès Géol.,' vol. vii, (p. 667, &c.), also contains a *résumé* of the facts and theories relating to the Mesozoic rocks of Virginia, &c. Besides the reports of the State-geologists on the several districts wherein these sandstones and shales are developed, there are numerous papers in Silliman's 'American Journ. of Science and Arts,' and in the 'Proceedings of the Boston Nat. Hist. Society,' and of the 'Philadelphia Academy of Sciences,' that elucidate the geological and palæontological characters of these Mesozoic tracts. The paper 'On the Relations of the Fossil Fishes of the Sandstone of Connecticut and other Atlantic States (or the Newark Sandstones) to the Liassic and Oolitic Periods," by W. C. Redfield, 'Amer. Journ. Sc.,' new ser., vol. xxii, p. 357, and another paper, in the 'Edinburgh New Phil. Journal,' new series, vol. v, p. 369, by Messrs. J. H. and W. C. Redfield, "On the Relation of the Post-permian Fishes of Connecticut and other Atlantic States to the Triassic and Jurassic Periods," are important in the history of the subject.

[1] 'The Geology of Pennsylvania,' &c., 4to, 1858. In vol. ii (part 2), p. 667, &c., these red shales and sandstones of "Lower Secondary Age" are treated of. Their fossils and probable place in the geological scale (Lower Jurassic, according to W. B. Rogers' latest views), are mentioned at p. 693. The relations of the several belts of these Mesozoic shales and sandstones on the Atlantic slope are treated of at p. 697. The conclusion arrived at is that the formation in question "was created in the period which unites the Triassic and Jurassic ages" (p. 697).

belonging to the Pennsylvanian series will be given further on (page 93); but I cannot indicate the exact place which these bituminous shales hold in the series.

3 and 4. Eastern Virginia. One area of carbonaceous shales and sandstones reaches from Campbell to Bucklington; another is situated on the James River, in the vicinity of Richmond. At the latter place are seen—1. (at top) Conglomerate; 2. Shales with Cycads and Ferns; 3. Grey sandstones, shales, and conglomerates; 4. Coal-seams and bituminous shale (with *Estheriæ*): altogether about 800 feet thick, and resting on granite.

5. North Carolina; on the Dan River, over a tract reaching from Leaksville to Germanton, are shales and sandstones having the following order of succession from above downwards :—

7 and 8. Grey and red marly sandstones.
6. Dark-coloured shales, with Cycads.
5. Conglomerate.
4. Grey sandstone.
3. Black and green slates[1] and coal (see section below). *Estheriæ* and *Cypridæ;* Fish-bones.
2. Brown sandstone.
1. Conglomerate.

At page 31 of Emmons's 'American Geology,' part VI, 2nd edit., from which the information respecting the Dan River and Deep River districts is obtained, the following section of the black and green shales with coal at Egypt Pit, Dan River, is given—

	Ft.	in.
Soil	30	0
Black slate, with *Cythere* [?]	16	0
Calcareous shales	12	0
Black slate, with *Cythere* [?] and *Posidonia* (*Estheria*)	25	0
Green calcareous shales	53	0
Black bituminous slates. Fossils. [Here and below "the *fossils* referred to are mostly *Cytheres* and *Posidoniæ*, and occasionally Fish-bones," p. 32]	35	0
Calcareous shales	4	0
Black bituminous slates. Fossils	45	0
Iron-balls. Gas	1	10
Black slate. Fossils	28	0
Calcareous shales	15	0
Hard black slate	13	0
Black slate and iron-balls	3	8
Sparry, calcareous, greenish shales	14	0
Black slate. Fossils	26	0

[1] "Slates" is a term used apparently by the American geologists for indurated shales (hard laminated argillaceous rock), and is not intended here to indicate real slate.

	Ft.	in.
Black slate and iron-balls	2	2
Hard sandstone	1	0
Black slate, fire-clay, and iron-balls	34	0
Black slate, beds of argillaceous iron, and balls	48	0
Sandstone	1	10
Black slate and iron-balls	1	4
Sandstone	3	0
Black slate and iron-balls	9	0
Bituminous coal	3	6
Black band	1	3
Bituminous coal	0	7
Black band	1	13
Bituminous coal	0	7
Black bituminous slate and iron-balls	8	0
Grey sandstone [saline, see Emmons, 'Amer. Geol.,' part vi, p. 96] and fire-clay	16	0
Black band	1	3
Coal	1	0
Black band	1	3
Black slate.		

6. The North and South Carolina tract, from Orange to Anson, on the Deep River. The following is the section.

Triassic, according to Emmons.

I. Red and mottled sandstones, slates, and marls, 1000 feet. *Estheriæ* and *Cypridæ;* also a Fish-scale (in a Coprolite), Saurian bones, and a Bird-bone.

H. Grey sandstone, 300—500 feet. Plants, Saurian bones.

G. Blue shale. Cycads, and other Plants
F. Conglomerate, including beds of sandstone } 40 feet.

(There is probably an unconformity of the beds here.)

"Chatham group" (Emm.) Permian, according to Emmons.

E. Grey, thin-bedded sandstone,[1] often rippled. Fucoids. 1200 feet.

D. Bituminous shales (*Estheriæ* and *Cypridæ*), with calcareous shale, in their upper part, and comprising coal-seams and iron-stones, 700 feet. Plants, *Entomostraca*, *Astarte* (?), *Mytilus* (?), Fishes, Reptiles, and Mammal (*Dromatherium*).

C. Bituminous slate, alternating with grey sandstone, and passing downwards into red and brown sandstone (Coniferous Trees and Fucoids), 1000—3000 feet.

B. Conglomerate, 50—60 feet.

A. Taconic slates.

Looking at these sections (and including that of the northernmost of the areas, as seen

[1] In speaking of this sandstone, Prof. Emmons says: "When the rocks are bare in dry weather during the summer they are incrusted with a salt which consists mostly of the chloride of sodium. So also the sandstones from the Egypt Pit, at the depth of 450 feet, decompose, and a nearly pure salt effloresces upon the surface while this process is going on, yet no gypsum has been found in this series up to this time." (Page 96.)

at Greenfield, Conn.), we may observe a nearly general coincidence in the occurrence of Upper and Lower Conglomerates, which may possibly be a guide in correlating the deposits of the several areas. As little, however, has been determined strictly as to this correlation as has been fixed with regard to the exact geological age of this great group of strata.[1] Prof. E. Emmons has sketched out the members of the Deep River series (estimated at upwards of 6000 feet in thickness); he indicates two chief horizons, far apart, at which Saurian remains, Plants, *Estheriæ*, and other fossils, occur; and he believes that the distinctions of the fossils are so great, the amount of accumulated deposit so vast, and the evidence of unconformability so important, that he has reason to refer the lower portion of the series (Chatham group) to the Upper Palæozoic (Permian), and the upper portion to the Lower Mesozoic (Triassic) age respectively.

This conclusion seems to me invalid, and the palæozoic evidences are very poor indeed; but it does not concern us at present, the *Estheriæ* alone demanding special attention; and of these I have seen specimens only from Dan River, from Richmond, and from Pennsylvania, none from the Deep River series. Prof. Emmons figures a specimen from the Chatham series (*Posidonia ovalis*), and two forms from Dan River (*P. multicostata* and *P. trigonalis*). If the conglomerates in the several basins should be indicative of certain correlative horizons (as above referred to), all these *Estheriæ* would apparently belong to the same (lower) group; and the *Estheriæ* of Richmond, Va., would seem to belong to the same horizon. Prof. Emmons, however, refers the Richmond coal-field to the age of the upper part of the Deep River series (if I understand him aright).

I have not been able to discern any essential difference between the *Estheriæ* from Pennsylvania, Virginia, and Dan River (North Carolina); and they might therefore well belong to the same horizon, whatever those from the Deep River series may turn out to be. Of the latter we have figures, given by Prof. Emmons, which help us, however, little or nothing in specific determination, for I am quite prepared to say that ordinary artists and amateur draughtsmen would make as many and as variable sketches of one and the same *Estheria*, in different states of preservation, as the three given us of *P. multicostata*, *P. angularis*, and *P. ovalis*, and we will include also the far better wood-cut of the Richmond *Estheria* given by Lyell. The last mentioned is equivalent to our fig. 28! Fig. 28 represents the same species as do figs. 26 and 27. And specimens of

[1] If the reader will consult Prof. H. D. Rogers's 'Essay on the Geology of the United States,' in the last edition of A. Keith Johnston's 'Physical Atlas,' he will there find the stratigraphical conditions of the Mesozoic sandstones and shales under notice amply and, I believe, correctly treated. Whatever may be the thickness of the several strata, measured perpendicularly and added together,—a thickness far surpassing, in Connecticut, according to Prof. Hitchcock, that of either the Triassic or the Jurassic strata of Europe ('Elementary Geology,' new edition, 1860, p. 409), yet, as these deposits have been formed in confined areas, and on sloping shores, it appears to me that Prof. Rogers' observations must satisfy any dynamic geologist that no great vertical displacement of the area has been required for the accumulation of this sedimentary mass in the shallow waters of the old sub-Appalachian water-belts.

the same occur sufficiently distorted, or otherwise modified, to be sketched like the rough figures, above alluded to, which are copied at pages 86 and 87.

Further, Mr. Conrad appears to have identified *P. multicostata* with *P. ovata* (Lea), and *P. triangularis* with *P. parva* (Lea); and of Lea's species we can judge by our own Pennsylvanian specimens, which agree with those from Richmond and Dan River, there being evidence of one species only.

Of *P. ovalis*, Emmons, we learn, that it is "common in the shales of the Richmond basin," as well as in the Lower (Chatham) shales of the Deep River series; and, indeed, the Dan River series is mentioned in connection with its occurrence. At all events, it appears that we may expect to find it among our Richmond specimens; and hence I believe that it merges, with the rest, into the one species which appears to have an enormous range, horizontally and vertically, in this great series of Lower Mesozoic deposits in North America.

In 1857 a few specimens of fossil *Estheriæ* from the black shales of Pennsylvania, Virginia, and North Carolina, were confided to me by the Professors W. B. and H. D. Rogers. Though some of these seemed at first sight to be tolerably well preserved, and to belong to two or even three distinct forms, yet, on examination, the difficulty of discriminating any real differences of feature and structure has been found to be very great, if not impossible. The results, however, arrived at as to the determination of species is given above.

I cannot make as full and exact a comparison of the North American fossil *Estheriæ* with those of Mángali and of other places as I should have wished; but we can learn much respecting the palæontological associates of the *Estheriæ*, and of the probable mode of the deposition of the strata in which they are found, from the accounts given of the Estherian shales of Pennsylvania by the geologists of the United States.

The *Estheriæ*, accompanied by *Cypridæ*, occur in the "Main Red Sandstone belt in Pennsylvania, Virginia, and North Carolina," in the short intermediate tract of Red Sandstone in Virginia, and in the more eastern tract in Virginia and North Carolina. Without, however, availing ourselves of the full descriptions of these strata given by Rogers,[1] Emmons,[2] and others, it will be sufficient to take the section exhibited by the cutting of a tunnel on the Reading railway at Phœnixville, Chester County, Pennsylvania, described lately by Mr. Wheatley; and this is the more interesting as the author gives a critical résumé of the reptilian and other remains found in the same group of strata, and offers some remarks on the apparent similarity of these with the Nágpur and Mángali beds. I therefore avail myself of the following communication made to the 'American Journal of Science and Arts,' 2nd ser., vol. xxxii (No. 94, July, 1861), p. 41, &c., mentioning at the

[1] 'Reports on the Geology of New Jersey, Virginia,' &c.; and especially the 'Final Report on the Geology of Pennsylvania,' 1858.

[2] 'Reports on the Geology of North Carolina,' &c., and 'American Geology,' part VI, 1857.

same time that I am indebted to Mr. Wheatley[1] for a polite reply to my inquiries respecting the section, and for an illustrative diagram (fig. 9, p. 95).

"*Remarks on the Mesozoic Red Sandstone of the Atlantic Slope, and notice of the Discovery of a Bone-bed therein, at Phœnixville, Pennsylvania.* By CHARLES M. WHEATLEY, M.A. (Read before the Connecticut Academy of Arts and Sciences, Feb. 20th, 1861.)

"No question in American geology seems more difficult of elucidation than the age and geological position of the so-called 'New Red Sandstone' of the Atlantic slope; some geologists referring it to the Oolitic or Liassic periods, others to the Trias, and others, still lower, to the Permian. The true position may probably be determined, like the San Casciano Beds, intermediate between the Liassic and Triassic periods, forming a separate group, containing, like those beds, its own peculiar fossils. No true Permian forms characteristic of that formation have yet been discovered; the fishes formerly referred to *Palæoniscus* are now placed in the genera *Catopterus* (Redfield) and *Ischypterus* (Egerton), their tails being more homocercal than heterocercal. The *Clepsysaurus* (Lea), once considered a Thecodont Saurian and analogous to *Thecodontosaurus antiquus* of Riley and Stutchbury from Redland, near Bristol, England (found in dolomitic conglomerate referred to the Permian, but now considered not older than the Triassic), is stated by Dr. Leidy ('Proc. Acad. Nat. Sci. Philad.,' June 9th, 1857) to be 'not properly a Thecodont reptile, but may form the type of a new family, as its teeth are inserted in the jaws by solid conical fangs.'.....Mr. Wheatley proceeds to correct Prof. H. D. Rogers in his distribution of the Reptilian remains ('Final Report on the Geology of Pennsylvania,' vol. ii, part 2, p. 695) said to have been found in Pennsylvania and New Jersey; and then states that "the following fossils have been noticed in the 'Mesozoic Red Sandstone' of Pennsylvania (chiefly from the shales excavated in the railway-tunnel[2] near Phœnixville.

"*Plants, Phœnixville and Gwynnedd.*

"*Equisetum columnare*, Brong., 15 to 16 in. long, and 7 in. circumference. In sandstone of a dark-grey colour, with iron-pyrites, Phœnixville.

"*Pterozamites longifolius*, Emmons. In grey micaceous sandstone, with iron-pyrites, Phœnixville.

"*Gymnocaulus alternatus*, Emmons. In light micaceous sandstone, Phœnixville. Fir-cones, 6 in. long, 1 in. wide, Isaac Lea, this Journ. [2], vol. xxii, p. 123, 1856, in black bituminous shales, Phœnixville.

"Plant resembling that figured by Emmons as *Calamites punctatus*. In black bituminous shales, Phœnixville.

"Plant resembling *Noeggerathia*, at Gwynnedd, I. Lea ('Am. Jour. of Sci.,' vol. xxii, 1856, p. 123), probably the same as figured by Emmons ('N. Car. Rep.,' pl. 1, fig. 3), as *Dictyocaulus striatus*, and which Prof. O. Heer (this Journal [2], vol. xxiv, p. 428) says 'has an obvious resemblance to *Noeggerathia*.'

"A number of plants, seed-vessels, &c., have been found in the grey micaceous sandstone and black shales at Phœnixville, the genera of which are yet undetermined.

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[1] Since this was written I have received a large supply of *Estheriæ*, and other fossils of the Phœnixville shales, from Mr. Wheatley. These will be noticed by themselves in the sequel.

[2] The position of this tunnel (Black-rock Tunnel), a little north of Phœnixville, Chester Co., is shown in the map of the mining district of Chester and Montgomery Counties, in Rogers's 'Geol. Pennsylvania,' vol. ii, part 2, between pp. 674 and 675.

"*Crustacea at Phœnixville and Gwynnedd.*

"*Estheria ovata* (*Posidonia ovata*, Lea) and *Estheria parva* (*Posidonia parva*, Lea), in black bituminous shales, Phœnixville (also at Gwynnedd).

"*Cypris*, two species, one smooth, the other beautifully granulate,[1] in black shales, Phœnixville, Rogers; also at Gwynnedd, J. Leidy ('Proc. Acad. Nat. Sci. Phil.,' June 16th, 1857).

"*Limulus* (?). Fragment of shield, probably *Limulus;* black bituminous shales, Phœnixville. Other remains, probably Crustacean, have been found in black shales, Phœnixville.

"*Mollusc from Phœnixville.*

"*Myacites Pennsylvanicus*, Conrad ('Proc. Acad. Nat. Sci. Phil.,' 1857, p. 166; and 1860, pl. 1, fig. 3). In the black shales, with *Estheriæ*.

"*Fishes at Gwynnedd and Phœnixville.*

"Single ganoid scale, in black bituminous shales, at Gwynnedd, Isaac Lea, this Journ. [2], vol. xxii, 123, 1856, more like *Pygopterus mandibularis*, Ag., than any other which had come under Mr. Lea's notice.

"Scales, bones, and teeth of ganoid fishes are abundant in black bituminous shales at Phœnixville. Scales have been found by Dr. Leidy and I. Lea also at Gwynnedd ('Proc. Acad. Nat. Sci. Phil.,' June 9th, 1857).

"*Turseodus acutus*, Leidy ('Proc. Acad. Nat. Sc. Phil.,' June, 1857, p. 167). 'This genus and species are founded upon a left dental bone, with teeth, probably of a ganoid Fish, which I obtained from the black shales of what have been usually considered the Triassic rocks, from near Phœnixville, Chester Co., Pa.'

"*Radiolepis speciosus*, Emmons. Family *Cœlacanthi*. Scale discovered at Gwynnedd by Isaac Lea, in black bituminous shales ('Proc. Acad. Nat. Sci. Phil.,' June 7th, 1857), also at Phœnixville.

"*Catopterus gracilis*, Redfield. Scales, bones, and teeth, similar to those from Richmond, Va., and North Carolina, are found in bituminous shales at Phœnixville.

"*Reptiles at Phœnixville, &c.*

"*Clepsysaurus Pennsylvanicus*, Lea ('Journ. Acad. Nat. Sci. Phil.,' new series, vol. ii, 1853, p. 185), founded on vertebræ, ribs, and teeth, discovered in calcareous conglomerate, Upper Milford Township, Lehigh County. Teeth, supposed to belong to this Reptile have been discovered by Dr. Leidy in black bituminous shales at Phœnixville ('Proc. Acad. Nat. Sci., Philad.,' 1859, p. 110).

"*Eurydorus serridens* ('Proc. Acad. Nat. Sci., Phil.' 1859, p. 110), founded on teeth, 'large size, compressed, conical, opposite acute serrulated borders,' discovered by Prof. Leidy in black bituminous shales, Phœnixville.

Composaurus —— ? Leidy ('Proc. Acad. Nat. Sci. Phil.' 1859, p. 110), founded on teeth discovered by Prof. J. Leidy in black bituminous shales at Phœnixville;—'borders without serrulations, base fluted; ..... resembles the teeth of *Composaurus* of the coal of Chatham Co., North Carolina, but nevertheless belongs to a different species.'

"*Centemodon sulcatus*, Lea ('Proc. Acad. Nat. Sci. Phil.,' vol. viii, p. 77, March, 1856), founded on a single tooth discovered by Mr. Lea in black bituminous shales at Phœnixville, described in this Journal [2], vol. xxii, p. 123. Bones and teeth, probably Batrachian, found by Dr. Leidy at Gwynnedd ('Proc. Acad. Nat. Sci. Phil.,' June 16th, 1857), in black bituminous shales; also at Phœnixville.

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[1] See also W. B. Rogers's remarks on these *Cypridæ* ('Proceed. Boston Soc. Nat. Hist.,' vol. v, p. 15, 1854).

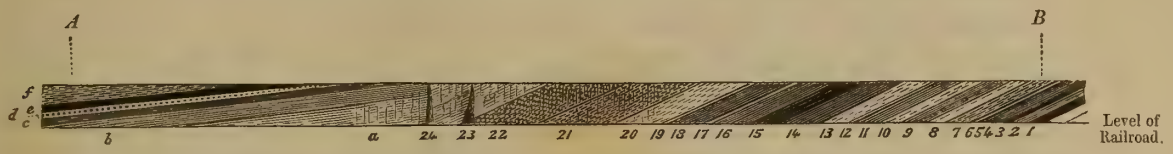
"Coprolites, very abundant in black bituminous shales at Phœnixville, some of them containing Fish-remains.

"Foot-tracks, *Chelichnus Wymanianus*, Lea, on dull-red limestone, Phœnixville, Isaac Lea ('Proc. Acad. Nat. Sci. Phil.,' viii, 77, 1856).

"Ripple-marks are also found in the red shale, Montgomery County, opposite Phœnixville."

The accompanying diagram of the strata exposed in the tunnel has been kindly supplied by Mr. C. M. Wheatley (November 23rd, 1861). The numbers in the following list of the beds correspond to those on the diagram.

FIG. 9.—*Section of the Strata in Phœnixville Tunnel, through Black Shale Hill, on the Reading Railway, Chester County, Pennsylvania.* Length of the tunnel, from *A* to *B*, 2000 feet.



A. East end of the tunnel; from hence the "Mesozoic Red Sandstone" extends about ten miles, to near Norristown; but, as far as examined, it contains no other black bituminous shales.

B. From this, the west end of the tunnel, the "Mesozoic Red Sandstone" extends about thirty miles, to near Reading; but, as far as examined, without any other bituminous shales.

a. Hereabouts is a sandstone full of Plants, and with Saurian teeth in large numbers, and bones of Saurians. From *a* towards *b* the strata are irregular. (*a*, Shale and sandstone; *b*, Red shale.)

"*Section of Strata at Phœnixville Tunnel, Pennsylvania, beginning at the eastern entrance, and running about two thirds through; dip north-west.*

	Ft.	in.
"1. Red shale	5	0
2. Green shale	6	0
3. Black bituminous shale, containing Saurian bones, coprolites in abundance, *Estheriæ*, remains of ganoid Fishes, and *Cypris*; there are clay-concretions, about 1 in. in thickness, in the upper part	1	10
4. Red and green shales, the green slightly calcareous, with traces of *Estheriæ*; and iron-pyrites	11	0
5. Black bituminous shales, with scales of ganoid Fishes, *Estheriæ*, and *Cypris*; fossils not very abundant	1	0
6. Dark-green, hard, compact shale, full of clay-concretions; traces of *Cypris*	0	9
7. Red micaceous sandstones	7	10
8. Brown sandstone, with calcite veins and quartz crystals	8	6
9. Hard, compact, red, and green shale, with nodular concretions of limonite abundantly distributed all through it, forming a hæmatitic conglomerate	5	8
10. Red sandstone, with remains of Plants	5	6
11. Red and green shale	5	2
12. Red shale, with Coprolites and Plants, the Coprolites enclosing scales of ganoid Fishes	0	10
13. Grey sandstone, with veins of carbonate of lime	5	5
14. Fine-grained, red and green, variegated shale	24	0

		Ft.	in.
15.	Black, bituminous shales, with *Estheriæ* and Fish-remains in upper part	6	0
16.	Grey, compact, fine-grained shale	11	0
17.	Olive-green shale, with red veins	1	0
18.	Red shale	7	0
19.	Clay-concretions, in three layers, 1 in. each	0	3
20.	Sandstone, with veins of dolomite and calcite in cleavage, which is quite vertical	11	3
21.	Fine-grained micaceous sandstone (estimated)	20	0
22.	Fine-grained compact sandstone (estimated)	25	0
23.	"Vug," or cavity, 5 ft. wide at bottom of tunnel, 21 ft. high, running to a point about 2 ft. above the back of tunnel, filled with red and green shales, talcose and micaceous, crushed to powder.		
24.	White talcose shale, vertical, 5 ft. wide at bottom, 4 ft. at top of tunnel.		
25.	Red shale, fine-grained, compact	6	8
a, b.	Strata very irregular for some distance. [Shale and sandstone.]		
c.	Shale, with clay-concretions and oxide of iron	0	10
d.	*Bone-bed*, full of Saurian bones; no other fossils noticed	0	6
e.	Black bituminous shale, with *Estheriæ* and Coprolites	0	6
f.	Fine-grained, hard, compact sandstone, full of stems of Plants	6	0

"The 'bone-bed' is situated about 100 ft. in the tunnel from the western end, and is not more than 6 in. thick. Fragments of Saurian bones occur rather abundantly all through the layer, but the more perfect bones are found at the bottom of the bed, where they are collected together, forming from 2 to 3 in. of the layer; a seam of white or pink carbonate of lime underlies them, and is from $\frac{1}{8}$ to $\frac{1}{2}$ in. in thickness. Under this is a very thin seam of black carbonaceous matter, which is grooved and polished like 'Slickensides,' evidently showing [the action of] great disturbing force since the deposition of the bed.

"The material composing the bone-bed is formed almost entirely of the remains of *Cypris*. No Estherias Myacites, Coprolites, nor Fish-remains have been observed associated with the Saurian bones in many tons of the shale carefully broken up and examined.

"Above the bone-bed is about 6 in. of bituminous shale with *Estheriæ* and Coprolites; over this from 5 to 6 ft. of hard, fine-grained sandstone, with Plants. The bed (bone-bed) is underlaid by 10 in. of shale with clay-concretions, which are mostly geodes, containing yellow, pulverulent oxide of iron, and under this a compact, fine-grained, red shale, from 6 to 7 ft. to the bottom of the tunnel.

"Near the above, in a micaceous dolomitic sandstone, of a light-grey colour, occasionally so calcareous as to effervesce freely in acids, occur Saurian bones, and part of a jaw, 7 in. in length, $\frac{7}{10}$ in. wide, and about $\frac{8}{10}$ in. deep, with seven alveoles about $\frac{3}{10}$ in. apart,—a cranial plate, radiated and sculptured, $1\frac{1}{2}$ in. long and $1\frac{2}{10}$ in. broad,—an Ichthyodorulite, 3 in. long $\frac{3}{10}$ in. wide at base,—remains, probably, of Batrachians,—*Estheriæ*,—and bones, scales, and teeth of ganoid Fishes; the scales are large, thick, beautifully ornamented, and coated with a layer of transparent enamel (ganoin).

"Casts of two shells; one may probably be referred to either *Pholadomya* or *Cardita*, and the other to *Unio* or *Potomomya*, and also large quantities of Saurian teeth, some of which are full $1\frac{1}{2}$ in. in length, curved, smooth, or finely striated, probably belonging to *Clepsysaurus Pennsylvanicus*, Lea; others curved and sulcate, and answering to the description of *Centemodon sulcatus*, Lea. Another, perhaps, may be *Composaurus*, Leidy, and another of 'large size, compressed, conical, with opposite acute, serrulated borders,' which doubtless is that described by Prof. Leidy as *Eurydorus serridens*. These teeth are found twenty or thirty together, and are well preserved; sometimes the teeth are converted into iron-pyrites for one half their length, or the pulp-cavity alone filled with pyrites; and occasionally small seams of dolomite, calcite,

or sulphuret of iron, cross them transversely without disturbing their position. It is remarkable that, while the black bituminous shales have afforded but few Saurian teeth, and none have as yet been discovered in the 'bone-bed,' so many should have been collected together and deposited in this stratum of dolomitic sandstone as to give it the appearance of an osseous conglomerate or a bone-breccia.

"In some instances the casts only of the teeth remain, the substance of the tooth being converted into dolomite, but retaining the exact form of the tooth, with the sulcations as distinct as in the original. Twenty teeth, of probably three or four genera of Saurians, all converted into dolomite, occur on a piece of sandstone 6 by 3 in. It is a singular fact that, while the teeth are dolomitic casts only, the bones in the same stone remain unchanged, retaining their original structure.

"Associated with the above fossils in the sandstones are numerous Plant-remains, mostly of a broad sulcated stem, without joints or branches; as far as noticed, they retain the same width their entire length, and are from ½ to 2 in. broad and from 6 to 8 in. long.

"The shales, sandstones, and fossils of the Phœnixville Tunnel bear a remarkable resemblance to those of Nagpur and Mangali, Central India, described by Messrs. Hislop and Hunter ('Quart. Journ. Geol. Soc.,' vol. x, p. 472, and vol. xi, p. 371, 1854), and referred by them [at that time] to the Lower Jurassic age. The following is the descending order of the series according to the observations of the authors:

"1. Soft ferruginous sandstone, sometimes hard, with iron-bands and Plants.

"2. Fine and coarse argillaceous sandstones, rich with Plant-remains; these have afforded—

- "Labyrinthodont reptile, *Brachyops laticeps*, Owen.
- "Fishes; ganoid scales and small jaws.
- "Crustaceans; *Estheria*.
- "Plant-remains: Fruits and seeds, numerous and undescribed; Leaves, Conifers, Zamites, Poacites, and Ferns (*Pecopteris, Glossopteris, Tæniopteris, Cyclopteris, Sphenopteris*); Stems, exogenous and endogenous; Acrogens, *Aphyllum, Equisetites, Phyllotheca, Vertebraria* (?).

"3. Red shales 50 ft., green shales 30 ft. In the former of these there were observed at Korhádi—

- "Reptilian foot-tracks.
- "Worm-tracks, and intestine-shaped evacuations; these were also found in the green shales.
- "*Phyllotheca* (?).

"4. White and coloured dolomitic limestones.

[There are also in some parts of the above series—]

- "Bituminous shales with fossils, [and] sandstone.
- "Indurated green clay-stone, green shale, [and] bituminous shale with fossils.

"The Plant-bearing sandstone of Phœnixville Tunnel, though not containing all the genera of Plants found in the [Nagpur and] Mangali strata, is far richer in Saurian remains, Crustaceans (*Estheria* and *Cypris*), parts of Ganoid Fishes, and Shells. The green shales of the tunnel have Worm-tracks and the intestine-shaped evacuations. The bituminous shales are rich in organic remains. The remains of *Coniferæ, Zamites, Equisetites*, and probably fruits and seeds, with dolomitic sandstones, indicate a very great similarity with the Lower Jurassic Central Indian formation." (See above, pages 79, &c.)

Habitat of Estheria ovata.—The fossil *Estheriæ* of North America, as far as I can learn, have no marine associates (omitting the Fishes, for reasons already given), except the little *Myacites Pennsylvanicus* and another, which are sufficiently obscure to be left unregarded. The *Cypridæ* associated with the *Estheriæ* at Richmond and elsewhere are like our recent *Candonæ*, and may well be supposed to have lived in fresh water. (See Appendix.) The long, narrow areas within which the Estherian and carbonaceous shales of the Atlantic slope were deposited may be regarded as having probably been favorable for the development of freshwater and brackish lagoons, rather than for sea-creeks freely open to the ocean (Rogers).

There is evidence of the presence of salt in some of the sandstones forming part of these Lower Mesozoic series of coal-bearing sandstones and shales. But these saline sandstones are above and below the zones of *Estheriæ* (according to Emmons), with considerable thicknesses of beds intervening (see above, page 90).

Estheria ovata from Phœnixville, Pennsylvania.—The collection of Estherian shales forwarded from Pennsylvania in May last, by Mr. C. M. Wheatley, in courteous compliance with my request to be supplied with some good material for this Monograph from the tunnel near Phœnixville, comprises a large number of specimens of black, grey, purple, and green shales, often crowded with *Estheriæ;* but the carapaces are rarely in a sufficiently good state of preservation to yield the desired information respecting their shape and ornament, far less their structure. Besides the common broadly ovate form of carapace-valve, such as appears to be characteristic of *E. ovata* (see Pl. II, figs. 26—28), and many individuals of smaller size and with thickly crowded ridges, I find among Mr. Wheatley's specimens a few of a *narrower* form, somewhat resembling the Indian specimen figured in Pl. II, fig. 16. These narrower and longer carapaces probably differ from the others merely as individuals, and can scarcely be regarded as indicating a variety, certainly not a distinct species. Indeed their shape may be due to oblique pressure, or to the imperfect exposure of the margins, in these hardened and much crushed shales. Such as these have, in all probability, been the foundation of Prof. Emmons's *E. multicostata* and *E. ovalis*, above referred to (pp. 86, 87).

The sizes of different specimens of *Estheriæ* from Phœnixville are as follows:

	Broad forms.			Narrow forms.	
Height	$\frac{1}{10}$ inch.[1]	$\frac{8}{32}$ inch.	$\frac{3}{12}$ inch.	$\frac{7}{32}$ inch.	$\frac{8}{32}$ inch.[2]
Length	$\frac{1}{8}$ „	$\frac{10}{32}$ „	$\frac{4}{12}$ „	$\frac{10}{32}$ „	$\frac{14}{32}$ „

[1] These small individuals are thickly striated with their numerous fine ridges, and appear to me to differ from the larger individuals in having lived under conditions less favorable to their growth.

[2] The individual here measured is possibly somewhat imperfect on the ventral edge, and may therefore have been a little higher (broader) originally.

The specimens of shale have the following characters:

1. Hard, black shale (sometimes breaking up rhomboidally), fine-grained and micaceous, with shining, black, filmy carapace-valves of *E. ovata* on the planes of bedding. One specimen has the large form of carapace on one plane, and small, thickly striated individuals on another.

2. Hard, black shale, like the above, with a zone of *Cypridæ*, and with an individual having the *narrow* form of *E. ovata*.

3. Hard, black shale, granular with *Cypridæ*, being almost entirely made up of these little Entomostracans; containing also Coprolites (of Saurians?), and shining, black, filmy, crumpled valves of *E. ovata* on the bed-planes.

4. Hard, dark-grey shale (weathering rusty on the planes of bedding), containing small individuals of *E. ovata*, finely striated by their numerous, crowded ridges; those on one plane are almost squeezed away, those on the other retain black remains of their carapaces.

5. Hard, dark-grey shale. Three thin bands of the dark, hornlike carapaces of *E. ovata* crop out on a sloping edge (weathering olive-coloured); besides the crowded layers, fragments of valves are scattered between. Though apparently well preserved, these carapaces show no good traces of sculpturing or structure.

6. A similar shale, bearing a largish individual, with the *narrow* outline.

7 and 8. Purple-grey shale (weathering ferruginous), and greenish-grey hard shale (weathering light olive-green), containing a few of the smaller individuals of *E. ovata*, with crowded ridges, on the bed-planes.

9. Green shale, with *Estheriæ* similar to those in Nos. 7 and 8, but showing the vertical bar-ornament figured in Pl. II, fig. 37. An important link is here supplied between these small *Estheriæ* and the larger form of *E. ovata*, their relatively small size and the crowding of their ridges alone remaining as distinctions. If living under disadvantageous circumstances, a usually large carapace might be stunted in growth, and its periodical peripheral additions would be small; producing features such as we have in this case.

In his 'Hist. des Progrès de la Géologie,' vol. viii, 1860, M. le Vicomte d'Archiac has embodied all the information down to 1859 respecting the Lower Mesozoic sandstones and shales of Massachusetts, Connecticut, New Jersey, Virginia, &c., under the heading "Formation Triasique," pp. 609—633; and here I may supply the references to the same valuable work, that I inadvertently omitted when treating of *Estheria minuta*. The Triassic formation of Würtemberg and other parts of Germany are described at pp. 426—549 of the same volume (viii, 1860); those of Alsace, at pp. 134—149; and those of England at pp. 16—50; and the strata of Rhone Hill, Tyrone, whence *E. Portlockii* was derived, are treated of at p. 12.

M. d'Archiac, in speaking of the Triassic period, in his masterly *résumé* of all that had been done towards its elucidation (1860), remarks that, of the several geological formations, the Triassic is one of the most curious to study—one of those which most strongly interests the naturalist, as much by the variety of the inorganic phenomena connected with its origin as by the singular distribution of organized beings which then peopled the earth. I must here express a hope that in the study of the history and relations of these most interesting deposits some aid will be found in the foregoing pages, treating of *Estheria minuta* of the true Trias, of its variety *Brodieana* in the Rhætic beds, and of the Lower Mesozoic *Estheriæ* of India and North America.

10. Estheria Murchisoniæ, spec. nov. Pl. III, figs. 1—12.

Tellina (?), *Murchison*. Transact. Geol. Soc., 2nd ser., 1827, vol. ii, p. 311.

Inch.		Inch.	
Height ..... $\frac{3\frac{1}{2}}{12}$	Proportion 27 to 42, or 1 : $1\frac{1}{2}+$.	Height, more than $\frac{4}{12}$	Proportion 17 to 33, or 1 : 2—.
Length ..... $\frac{3\frac{1}{2}}{12}$		Length ..... $\frac{5\frac{1}{2}}{12}$	

Carapace-valve nearly elliptical, the straight hinge-line interfering with the symmetry of the outline. The umbo is forward, at the end of the hinge-line, and scarcely affects the outline. The anterior extremity has a flatter curve than the posterior. About eighteen delicate concentric ridges are usually distinctly to be observed, with their rather wide interspaces (figs. 1, 3, 4, 5, &c.); but some carapaces have nearly thirty ridges, with very narrow interspaces (figs. 2, 6, 7). The ornament of the interspaces is essentially a bold, irregularly hexagonal reticulation (figs. 5 and 12), like that of *E. minuta* (Pl. II, fig. 3); but it generally takes on (or passes into) a distinct, short, vertical wrinkling at the lower part of the interspace (figs. 5, 7, 11). This sometimes presents the modification seen in figs. 3 and 8, where the wrinkling is of a much smaller pattern, and reaches half way up, or all across, the interspace. Sometimes a delicate, horizontal wrinkling interferes with (fig. 4), or replaces (fig. 9) the vertical wrinkles, without hiding altogether the reticulate structure of the shell. Not unfrequently, both the broad and the narrow interspaces are blank (figs. 6 and 10).

The carapace-valves of this beautiful *Estheria* have been converted into calcite, but are otherwise little altered by fossilization, except being somewhat compressed and rendered silvery white, and will bear comparison with the carapaces of any recent *Estheria*. Nor have we far to seek for a modern representative of this Jurassic form. *E. Dahalacensis*, Durckh. (from the freshwater marshes of the Island Dahalac, Abyssinia), figured and described by Dr. Baird, 'Zool. Soc. Proceed.,' 1849, p. 89; *Annulosa*, pl. 17, figs. 2—4, has but a trifling difference in the outline and the number of ridges; and its reticulate ornament is the same as that of *E. Murchisoniæ*, except that the tendency to develope the vertical wrinkles seems to be wanting. But the latter ornament, associated with the reticulation, just as in *E. Murchisoniæ*, is beautifully shown in a somewhat differently shaped *Estheria* from India (*E. Boysii*, Baird, 'Proc. Zool. Soc.,' 1839, p. 89, *Annulosa*, pl. 11, fig. 6).

In the Museum of the Geological Society, among a collection of fossils brought from the Western Islands of Scotland by Sir Roderick Murchison in 1827, is a specimen of bluish marl from Skye, labelled "Canal, Icolmkill, Skye," bearing on one surface a crowded layer of the delicate *Estheriæ* described above. These are alluded to by Sir R. Murchison as "*Tellinæ* (?)" in his memoir "On the Coal-field of Brora, in Sutherlandshire, and some other Stratified Deposits in the North of Scotland," in the 'Transact. Geol. Soc.,' 2nd

series, vol. ii, part 2, p. 311; where he says, referring to some strata in Skye, "That the strata of this series [with *Belemnites abbreviatus*, Mill., and *Ammonites Murchisoniæ*, Sow., &c., Middle and Lower Oolite] were originally continuous from the high cliffs between Portree and Holme to the low coast on the opposite side of the island, as stated by Dr. MacCulloch, I can confirm, having found several fossils in blue shale [calcareous], through which a deep canal has recently [1826] been cut by Lord Macdonald, to drain the Lake of Mugsted. Among these shales are the *Ammonites Koenigi*, *Ostrææ* in masses, many *Belemnites*, flattened *Tellinæ* (?), &c."

Estheria Murchisoniæ is dedicated to Lady Murchison, the accomplished wife of the discoverer of this interesting fossil. It probably belongs to some freshwater or estuarine deposit of the Middle Oolite (Oxfordian).

11. Estheria concentrica, *Bean*, sp. Pl. III, figs. 13—17.

Cypris concentrica, *Bean*. Mag. Nat. Hist., 1836, vol. ix, p. 376, fig. 54.

Inch.		Inch.	
Height	$\frac{7}{24}$	Height	$\frac{9}{24}$
Length	$\frac{9}{24}$	Length	$\frac{12}{24}$
Thickness	$\frac{4\frac{1}{2}}{24}$		
Proportion 1 : $1\frac{1}{3}-$, by $\frac{1}{2}+$.		Proportion $\frac{3}{4}$: 1.	

Carapace suboviform; truncate and very slightly curved at one end (posterior?), well rounded, and narrower, at the other; nearly straight on the dorsal and ventral margins; umbos large, slightly projecting over the straight hinge-line, nearly at its centre. The dorsal profile of the carapace (fig. 14) is acute-elliptical, somewhat sharper at one end (anterior?) than at the other. The surface is marked with very numerous (60?) closely set ridges or wrinkles and intermediate striæ; the latter are seen, in the interspaces (when these are broad enough), to accompany an obscure reticulation, or linear dotting, parallel with the striæ (fig. 15).

In Loudon's 'Magazine of Natural History', 1836, vol. ix, p. 376, Mr. William Bean gave a "description and figures of *Unio distortus*, Bean, and *Cypris concentrica*, Bean, from the upper sandstone and shale of Scarborough; and *Cypris arcuata*,[1] Bean, from the Coal-formation of Newcastle."

Unio distortus (fig. 53) is first described. The following is the description given of *Cypris concentrica* (fig. 54):—"Shell oval, convex, one end a little broader than the other, strongly wrinkled transversely, and covered with minute concentric striæ; the hinge-line is prominent, and this species has more the appearance of a bivalve shell than any of its congeners. Colour, pale brown. Length, nearly 4 lines. Breadth, 6 lines. The

[1] This is a *Beyrichia*, and is not uncommon in the Coal-measures.

monarch of this tribe. From the same place as the last, where it occurs sparingly in every part of the sandstone and shale, that contains vegetable remains.

"Only these two species of shells have yet been discovered in this interesting spot, and they are certainly of sufficient geological importance to deserve recording. Depressed specimens of *Cypris concentrica* are found also in the lower sandstone and shale at Cloughton and Haiburn Wyke."

The order of succession of the shales and sandstones beneath the Cornbrash on the Yorkshire coast has been given in detail by Dr. T. Wright, F.G.S., in the 'Quart. Journ. Geol. Soc.,' vol. xvi, p. 31, thus:

		Ft.	In.	
1.	Cornbrash.			
2.	Carbonaceous sandstone	40	0	Upper shales and sandstones.
3.	Siliceous rock	4	0	
4.	Grey clays	6	0	
5.	Grey sand-rock	8	0	
6.	Brown sand-rock	2	0	
7.	Whitish and carbonaceous sandstones, with stems of Plants	4	0	
8.	Carbonaceous sandstone, with stems of Plants	9	0	
9.	Sandy shales	10	0	
10.	Grey limestone. Fossiliferous, marine	18	0	
11.	Carbonaceous sandstone, with Plant-remains	6	6	Lower shales and sandstones.
12.	Carbonaceous shale	1	0	
13.	Dark-grey clay	4	0	
14.	Sandstone and clay, carbonaceous	2	0	
15.	Sandy clays. *Unio distortus* and Plant-remains	3	0	
16.	Carbonaceous shale. Plant-remains	1	0	
17.	Carbonaceous shales and sandstones	1	6	
18.	Carbonaceous shale. *Uniones* and Plant-remains.	4	0	
18*a*.	Shale and ironstone	2	0	
18*b*.	Sandstone	1	0	
19.	Shale (Gristhorpe Plant-bed). ESTHERIA CONCENTRICA	2	0	
20.	Sandstone	12	0	
21.	Ferruginous sand-rock. *Pholadomya, Cardium, Trigonia*	5	0	
22.	Sandstone	4	0	
23.	Ironstone-rock. *Lima, Serpula*	2	0	
24.	Shale and sandstone. Plant-remains	4	0	
25.	Dark-grey clay. Plant-remains and ESTHERIA CONCENTRICA	10	0	
26.	Oolitic rock (Millepore-bed). Fossiliferous, marine.	10	0	and more.

Dr. Wright remarks, bed No. 25 (the 26th beneath the Cornbrash of the Yorkshire coast) is "a dark-grey clay, containing the remains of Plants in its upper portion, and

comparatively unfossiliferous in its lower division. This bed is well seen in the coast-section at Haiburn and Stainton Dale cliffs, where it becomes more sandy and passes into the 'block-sandstone' which rests upon the Millepore-bed. Mr. Leckenby collected *Cypris? concentrica*, Bean, from the clays of this bed at Gristhorpe, where it is about ten feet thick."

Mr. Leckenby informs me (January 26th, 1861) that he has collected some three or four specimens of the fossil in question, and that Mr. Bean says that he may have found in all above a dozen examples. They have been found, he observes, in the bed No. 19 of Dr. Wright's list, the rich deposit of fossil ferns at Gristhorpe Bay, also in bed No. 25, both at Gristhorpe and north of Scarborough, and, "in short, wherever plants have been found, the 'Cypris' has been found, although most rarely, associated with them."

The finest specimens collected by Mr. Bean (figs. 13—17) are now in the British Museum; and, excepting some specimens of *E. minuta* from Pendock, are the best-preserved carapaces of fossil *Estheriæ* that I have seen. In size they greatly surpass these Triassic specimens; but they have their equals in that respect, and their superiors as to beauty of outline and ornament, in several of the *Estheriæ* figured and described in this Monograph. Few, however, if any, surpass them in geological interest—existing witnesses, as they are, of the old freshwater conditions of this portion of the European Jurassic area.

12. Estheria elliptica, *Dunker*. Pl. III, figs. 18—29; and Pl. IV, figs. 1—7.

Cyclas subquadrata, *Sowerby*. Fitton's 'Strata below the Chalk,' Trans. Geol. Soc., 2nd series, vol iv, part 2, 1836, p. 177 and p. 345, pl. 21, fig. 8.

Estheria elliptica, *Dunker*. Programm höh. Gewerbschule Cassel, 1843, p. 41; Stud. Götting. Ver. bergmänn. Freunde, vol v, part 2 (1843?), p. 175; Monographie Norddeutsch. Wealdenbildung, 1846, p. 61, pl. 13, fig. 33.

— subquadrata, *Dunker*. Stud. bergm. *l. c.*; Monogr., p. 62.

	English.	Adult German form.	Young German form.	Suborbicular variety.
Height ...	$\frac{13}{12}$ inch ..... $\frac{14}{12}$ inch	..... $\frac{4}{12}$ inch	..... $\frac{12}{12}$ inch	..... $\frac{03}{12}$
Length ...	$\frac{9}{12}$,, ... $\frac{23}{12}$,,	..... $\frac{6}{12}$,,	..... $\frac{14}{12}$,,	..... $\frac{3}{12}$
Proportion	19 to 26, or 1 : 1½—	10 to 16, or 1 : 1½+	23 to 38, or 1 : 1½+	15 to 22, or 1 : 1½—	33 to 36, or 1 : 1 +

Carapace-valves more or less elliptical or oval, sometimes suboblong. The two extremities are nearly equally curved in outline. In our English specimens (var. *subquadrata*, Pl. III, figs. 18—27), which are suboblong, sometimes the one end and sometimes the other appears to have the boldest curve, but the frequently crushed state of the valves makes this an uncertain feature. The well-preserved German specimens

present relatively large, oval, Anodon-like valves (Pl. IV, fig. 1), more acute behind than before; also some small, oblong, probably young valves (figs. 2 and 6); and thirdly, a suborbicular individual (fig. 3), curiously analogous to the subquadrate or suborbicular forms of *E. Manga-liensis* (Pl. II, figs. 20, 23) and *E. striata* (p. 26, fig. 2). The shape of the last reminds us of some American Unios.

Behind, the hinge-line (which in most specimens is equal to more than half the length of the valve) is lost in the curved slope of the postero-dorsal region; in front, it is ended by the umbo, which projects at the antero-dorsal angle above the convexity of the anterior margin, except in the young individuals from Hanover, in which case it is much less distinct (Pl. IV, figs. 2 and 6).

The surface of the valves bears twenty, and often many more, concentric ridges, which are usually much crowded towards the ventral border. The ornament of the interspaces consists of transverse wrinkles or vertical bars, sometimes branched and inosculating. These are coarser in the English variety (Pl. III, figs. 20—29) than in the German specimens (Pl. IV, fig. 7). The concentric ridges are often so closely set that the sculpturing is obsolete (figs. 4 and 5). In some specimens, from near Hastings, the lower edges of the ridges are delicately crenate (Pl. III, figs. 28, 29). Occasionally a granulate ornament accompanies the little vertical bars (fig. 20, from Bulverhithe).

The sculptured interspaces of *E. elliptica* are imitated in two recent *Estheriæ*. *E. donaciformis*, Baird ('Proc. Zool. Soc.,' 1849, p. 89, Annul., pl. 11, fig. 5), from Africa, has the inosculating wrinkles; and *E. similis*, Baird (op. cit., p. 90, pl. 11, fig. 7), from India, has the short, vertical bars, together with an exaggerated crenulation or beading of the concentric edges. These *Estheriæ* also more or less resemble *E. elliptica* in the shape of the carapace.

Of the North German specimens with which I was kindly supplied in 1858 by my friend, Professor Dr. W. Dunker, of Marburg (who also gave to Dr. Mantell the fine specimens now in the British Museum, and figured in Pl. IV, figs. 1—7), we learn, from his 'Monographie der Norddeutschen Wealdenbildung' (4to, Brunswick, 1846), that they occur in the black Cyrena-shale, with *Cypridæ*,[1] of the Obernkirchn and Südhorst districts in Hanover.[2] He describes them as follows:

"*Estheria elliptica*, p. 61 (Dunker, 'Progr.,' p. 41; 'Stud.,' p. 175).—Estheria valvis ellipticis, planiusculis, tenerrimis, membranaceis, concentrice leviter sulcatis et striatis, umbonibus obsoletis." The length is given as from $3\frac{1}{2}'''$ to $5'''$ and more; and in proportion to the height as 100 : 75.

Estheria subquadrata (p. 62) is described as somewhat smaller, less arched on the dorsal and ventral borders, and subquadrangular. This is probably immature (figs. 2 and 6 of our Pl. IV). The English variety, though adult, retains this form.

[1] See further on, Appendix. The *Cypridæ* are calcareous; the shale and the *Estheriæ* are not.

[2] The Wealden area of North Germany is also described in Giebel's 'Gæa Germanica,' p. 251, &c.

Dr. Dunker adds:—"Another very similar, but doubtful, form occurs in the lower calcareous and marly portion of the Wealden, near the Serpulite-beds, on the Süntel."

In the Rev. J. H. Austen's 'Guide to the Geology of the Isle of Purbeck,' 1852, p. 14, one of the Lower Purbeck beds (No. 128) is said to contain *Estheriæ*;[1] but these are impressions of Archæoniscal fragments, as the Rev. O. Fisher first suggested.

Dr. Fitton and Mr. J. de C. Sowerby have noticed the English form of *Estheria elliptica*, under the name of *Cyclas subquadrata* ('Geol. Trans.' 2nd ser., vol. iv. p. 177, and p. 345, pl. 21, fig. 8), as occurring at two localities near Hastings. Dr. Dunker did not observe this when describing his specimens; and he independently gave the name "subquadrata" to one of the forms he met with in Hanover. As the large forms of *E. elliptica* are typical of the species, and as the smaller and subquadrate individuals are either immature or varietal, both names are not required; but the type retains the appellation given by Dunker, and the twice-given name *subquadrata* belongs to the small form found both in Germany (with the type) and in England. In Dr. Fitton's memoir, "On the Strata below the Chalk," *loc. cit.*, pl. 21, fig. 8, we have a sketch of eight specimens of natural size, on a piece of shale, and an enlarged view of an individual, described by Mr. J. de C. Sowerby, at p. 345 of that memoir, as "*Cyclas subquadrata*: transversely oblong, with straight sides; strongly marked with lines of growth; flat (perhaps from pressure). Found at St. Leonard's, Sussex." The locality would more correctly be *Bulverhithe*; for at p. 177 *C. subquadrata* is said to occur in the "Hastings sand, East Cliff, Hastings, in soft, fine, sandy clay, not effervescent; also cliff west of St. Leonard's;" and at the first cliff (Bulverhithe) in this direction they are found in plenty.

The English Wealden *Estheriæ* that I have seen are from that portion of the formation known as the "Hastings Sand," and from two or three horizons in that series.

1. From the neighbourhood of Tunbridge Wells. This specimen, given to me by the late Dr. Mantell, is a hard, grey, fine-grained, sandy, micaceous shale or mud-stone, retaining casts of *Cyrenæ* and small *Paludinæ* on one bed-plane, and *Estheriæ* on another (about half an inch apart). The valves are represented by dark-brown films, mostly crumpled, and by impressions. A trace of the original bar-ornament (Pl. III, fig. 24) can here and there be detected.

The Hastings Sand of the neighbourhood of Tunbridge Wells has been well described by Mr. F. Drew, F.G.S., in the 'Quart. Journ. Geol. Soc.,' vol. xvii, p. 276, &c.; but I cannot indicate the stratum from which Dr. Mantell obtained the specimen under notice.

2. From the East Cliff, near Hastings; collected and communicated by Mr. S. H. Beckles, F.R.S., F.G.S. This is a hard, light-brown, fine-grained, micaceous, sandy shale, with numerous brown, crushed carapaces on a bed-plane, and with *Cypridæ* scattered in the matrix. Mr. Beckles informs me that this specimen was taken from the lower part

[1] The Rev. O. Fisher, F.G.S., informs me that he found these specimens and showed them to Prof. E. Forbes (then at work on the Purbeck beds), who thought they might be *Estheriæ*. It was upon this information that they were noted in his pamphlet by the Rev. Mr. Austen, who has lately shown them to me.

of the cliff, just above the "lowest shale" of Mr. Webster's section, published in the 'Transact. Geol. Soc.,' 2nd ser., vol. ii, p. 34, pl. 5. From this hand-specimen we have figs. 25—29 of Pl. III, some of which show the crenulate ridges and the bar-ornament of the interspaces.

3. From a higher horizon in the East Cliff, Hastings; collected by Professor Morris, F.G.S., and myself. A hardish, yellowish-grey, fine-grained, slightly micaceous shale, imbedding scattered carapace-valves.

4. A grey, indurated, fine-grained, micaceous shale, containing scattered, brown valves, showing their form and sculpture, and numerous fragments also, from the same locality and series as the foregoing; but its exact place not known. Communicated by Mr. Beckles.

The following section of the strata observed in the cliffs immediately east of Hastings,[1] shows the horizons at which *Estheriæ* are believed to occur in the Hastings Sand series.

Section of the East Cliff, Hastings.

	Feet.
Loam and clay, with thin ironstone, containing *Cyrena*	5
Grey and yellow sandstone, with Plant-remains. Bones at the base	25
Hard, blue, calciferous sandstone, used for building	2
Blue shale and ironstone	2
Blue, laminated, calciferous sandstone, softer and coarser than that mentioned above	2
Shales, with ironstone nodules. *Endogenites, Cyrena*	10
Soft sandstone, mostly white, ferruginous in parts, sometimes laminated. Plant-remains, vertical tubes (root-marks ?), *Cyrena, Paludina* ....about	100
Marly beds (ESTHERIA) and hone-stone, about 5 ft. [Morris and Jones.] ..... Shale, including ironstone, with *Cypridea Valdensis*, Fish-scales, and Insect-remains, 1ft. 3 in. [Binfield] ..... Four beds of hard sandstone, with iron-ore and shaly partings	30
Clays, blue, ochreous, lignitiferous, &c., with sandstone bands. [ESTHERIA and Insect-remains in the brown, sandy shale at the top. Binfield.]	20
Shales [Plant-remains, Insect-remains, and *Paludinæ* in the middle brown band. Binfield]	7
Bluish-grey sandstone and clay	20
Ironstone (lignitiferous), shale (ESTHERIA?), and sandstone—seen on the shore. About	10 (?)

Further to the east, the last-mentioned group of beds (*m m* of Mr. Webster's section,

[1] The upper portion of this section is chiefly based on data supplied by Mr. Clement Sharp to Mr. J. Pitter in 1855, and obligingly communicated to me in 1860. The lower part has been described by Messrs. Binfield, in the 'Quart. Journ., Geol. Soc.,' 1854, vol. x, p. 175; where, also, references to Webster's and Fitton's sections will be found. Dr. Fitton found *Estheria* in the East Cliff, and at Bulverhithe.

before referred to) forms part of the cliff (about 10 feet); and, according to Mr. Beckles, ('Quart. Journ. Geol. Soc.,' 1856, vol. xii, p. 290) is succeeded by—

	Feet.
Sandstone	4
Slate-coloured, compact clay	7
Light-coloured clay	4
Dark clay. (The lowest bed seen in the Sussex Cliffs.)	

5. Another locality for *E. elliptica*, var. *subquadrata*, is a low cliff, nearly two miles west of St. Leonard's, and three and a half west of the East Cliff, Hastings. It is at the first rising of the cliffs between St. Leonard's and Bexhill. The geological position of the shales forming this low cliff at Bulverhithe, and rich with *Estheriæ*, is not clearly evident at first sight, on account of the valley intervening between Bopeep (St. Leonard's) and Bulverhithe. It is probable that, by means of a fault of considerable downthrow, the upper portion of the Hastings Sand series has been here lost to sight, and that the section at Bulverhithe commences with beds lower in the series than the thick, soft sandstone of the Castle Rock, Hastings, and of the cliffs behind the western end of St. Leonard's. In this case the Estherian Shales at Bulverhithe would be at nearly the same horizon above the clays at the base of the series there, as Mr. Binfield's clays with *Estheria* are with respect to the lower clays of the eastern cliffs. The following is the section of the strata in the cliff at Bulverhithe and the succeeding cliffs to the westward.

Section of the Bulverhithe and Bexhill Cliffs, Sussex.

	Feet.
Yellowish-brown and grey shales, with a thin, grey ironstone	7
Bluish-grey and brown shales, with sandy seams. A few *Estheriæ*	2½
Brown and blue shales, and sandy seams. *Estheriæ* abundant, especially in the lowest bed	2½
Sandstone, and three shaly seams	20
Hard sandrock, with concretions and irony seams	4
Finely laminated grey sandstone and shale, with ferruginous concretions	3
Ferruginous sandrock	4
Soft, clayey, ferruginous, concretionary sandrock, blue-hearted	4
Ferruginous sandstone, with a seam of grey shale	About 10
Sandstone. (A well-marked stratum)	4
Dark-grey, sandy, lignitiferous shale, with a ferruginous band	3
Grey shale	3
Ferruginous sandstone	3
Olive-brown and bluish shales	6
Sandrock and ferruginous band	4
Red and mottled clay, concretionary, and containing irregular bands of stone.	More than 20 feet seen.

A considerable part of the above section is seen in Galley Hill, near Bexhill (fig. 10). West of Galley Hill, between it and the road leading from Bexhill to the beach, is a fault (accompanied with minor slips), which brings the red clays down again to the beach; and westward of this the shales and sandstones that overlie the clays form the surface-ground, undulating along the low cliffs from Bexhill to beyond Couden, and broken by some slight faults, until they reach Pevensey Sluice, where they sink beneath the marshes, and doubtless are succeeded, in the interval between that spot and Pevensey Castle by sandstones and other beds equivalent to the higher part of the series seen at St. Leonard's and Hastings.[1] The Estheria-shales are, therefore, not seen in this direction. They have not been detected (that I know of) in the strata near St. Leonard's, but they may probably be found in the railway-cutting behind Bopeep. The arrangement of the strata between St. Leonard's and the East Cliff does not admit of these shales coming into view; as the upper beds of the Hastings Sand series lie near to the sea-level, until they come up again at White Rock and under the coastguard-station. Rising still more in the Castle Hill and in the East Cliff, the lower strata are recognised, and among them beds with *Estheriæ* occur at two, if not three, levels along the cliffs, in the space of a mile or so. The horizon at which I have myself (in company with Prof. Morris) seen them is in a bed lying upon the hone-stone in the East Cliff, and about eighty feet above the bottom clays. About thirty feet lower down Messrs.

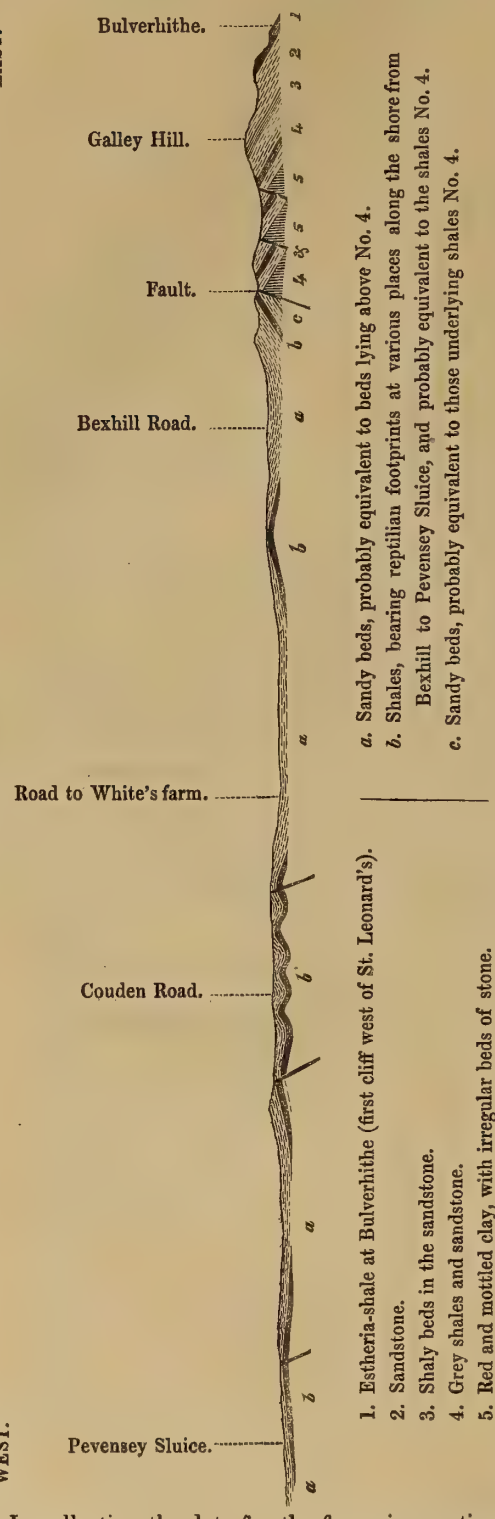


FIG. 10.—*Section of the Wealden Beds, as seen on the Coast to the west of St. Leonard's, Sussex. Length, 5 miles.*

[1] In collecting the data for the foregoing section, at various times, I have had the assistance of my friends, Prof. Morris, F.G.S., and Mr. A. Tylor, F.G.S.

Binfield noticed them, and I believe that Mr. Beckles has found them at another horizon, still lower by about forty feet. (See page 106.) As the equivalents of these lower shaly beds containing *Estheriæ* appear to me to occur along the Bexhill and Couden Cliffs (at a lower geological horizon than the Estherian shales of Bulverhithe, by about fifty feet), search might well be made there for these interesting little fossils. These are the shales which have afforded the Reptilian footprints to Mr. Beckles' researches.[1]

The specimens of Estherian shale (No. 5) under notice were collected by Prof. J. Morris, F.G.S., and myself at Bulverhithe[2] from the first set of strata met with in the first cliff westward of Bopeep (St. Leonard's). They consist of a soft, thinly laminated, bluish, fine-grained, micaceous shale, weathering grey and brownish grey. The valves are very numerous, but not in a good state of preservation, only very thin, brown films remaining, but these sometimes show both form and ornament very satisfactorily, as seen in Pl. III, figs. 18—21.

ESTHERIA ELLIPTICA, Var. SUBQUADRATA. Pl. III, figs. 18—29.

By this title, based on the trivial name used independently by Sowerby and Dunker, I designate our English form of *E. elliptica*, as at present known to me, and as described above (p. 103); because, although agreeing with the Hanoverian type of the species in general form, habit, and ornamentation, yet our specimens from Sussex uniformily differ in having smaller valves and a coarser bar-ornament. They may have possessed these varietal differences as inhabitants of deltaic or lacustrine waters different from, though coeval with, those of the German area.

The English Wealden *Estheria* (like that of Linksfield, p. 77) has not unfrequently passed for *Cyclas*, and occasionally in collections it has been labelled "Cyclas membranacea, Sow."; and this last-named shell has been quoted as an *Esthèria*.[3] There is no doubt, however, that *Cyclas subquadrata*, Sow., in Fitton's "Strata below the Chalk," 'Geol. Trans.,' 2nd series, vol. iv, p. 177 and p. 345, pl. 21, fig. 8, is the *Estheria* under notice.

13. ESTHERIA FORBESII, Spec. Nov. Pl. IV, figs. 8—11.

Height of valve	$\frac{3\frac{1}{2}}{1\frac{1}{2}}$ inch	more than $\frac{5}{1\frac{1}{2}}$ inch	$\frac{2\frac{1}{2}}{2\frac{1}{4}}$ inch.
Length.....	$\frac{5}{1\frac{1}{2}}$ „	less than $\frac{6}{2\frac{1}{4}}$ „	$\frac{3\frac{1}{2}}{2\frac{1}{4}}$ „
Proportion ...	10 to 15, or 1 : $1\frac{1}{2}$	31 to 35, or 1 : 1+	15 to 20, or 1 : $1\frac{1}{3}$.

Carapace-valves ovato-oblong in the adult (fig. 8), suborbicular in the young state

[1] 'Quart. Journ. Geol. Soc.,' vol. x, p. 456, where further references are given. See also the paper by Mr. A. Tylor on the same subject, *ibid.*, vol. xviii, p. 250, where a general section of the Sussex cliffs indicates the relative positions of these various shales.

[2] This is doubtless the "cliff west of St. Leonard's" where Dr. Fitton found *Estheria*.

[3] Jukes's 'Student's Manual of Geology,' 2nd edit., p. 605.

(figs. 9 and 10). Valve well rounded in front and behind, but somewhat obliquely; the antero-ventral and postero-dorsal margins sloping parallel to each other, and giving a somewhat rhomboidal outline to the full-grown shell. The ventral margin gently rounded in the adult, fully rounded and almost semicircular in the young state. The dorsal margin straight along the hinge-line, which occupies the middle of the border for a distance equal to more than half the length of the valve, and sloping off rapidly before and behind. Umbo distinct, terminating the hinge-line in front, and situated one fifth of the length of the valve from the anterior extremity. Ridges distinct, wide apart, about twenty-two in the adult; the interspaces ornamented with a delicate, irregularly hexagonal reticulation (fig. 11), with about seventeen meshes from ridge to ridge, and very similar to the ornamentation of *E. minuta*, var. *Brodieana* (Pl. II, fig. 15).

The species under notice is new; the specimens were collected in large quantities by Mr. David Forbes, F.R.S., F.G.S., three or four years since, at a place called Cacheuta, about 3500 or 4000 feet above the sea, on the eastern slope of the Andes, south of Mendoza; and I dedicate the species to this adventurons geological explorer of Chili, Bolivia, and Peru, some of the results of whose researches in these regions are published in the 'Quart. Journ. Geol. Soc.,' vol. xvii.

Mr. D. Forbes informed me that he discovered these fossils "in soft beds, together with abundant impressions of ferns, rushes, and reeds." He adds: "I found no other fossils. The beds are tilted, and in some places much altered by volcanic rocks, and appear to correspond with the beds in Darwin's section of Uspalata Pass,[1] in which he found a fossil forest."

E. Forbesii occurs in a pinkish-grey, finely laminated shale, indurated, and not breaking evenly along the lines of bedding. The carapace-valves are abundantly strewed throughout the shale, but do not lie very closely together; they are fawn-coloured, sometimes closed and filled with the matrix; generally separate, but not unfrequently in pairs, with the dorsal edges approximated, and sometimes retaining a considerable amount of convexity. Valves of young individuals are not uncommon among the others. Fragments of Ferns or Cycads and other obscure Plant-remains are scattered here and there.

The preponderance of the immature and somewhat suborbicular valves of this wide-ridged species on some specimens of the shale reminds one of the Pennsylvanian *Estheriæ*, when these have not their ridges crowded up into striæ. Moreover, the immature form of the South American species (Pl. IV, fig. 9) is much like a youngish individual of the North American *E. ovata* (Pl. II, fig. 26). They differ, however, in the dorsal angles; and the adults differ still more in outline, the narrower and exceptional form of *E. ovata* being scarcely worthy of being taken into account, as its shape may be due to oblique pressure or imperfect exposure of the margins of the valve. The pattern of ornament of *E. Forbesii* (Pl. IV, fig. 11) is not widely dissimilar from the reticulate

[1] 'Geology of South America,' p. 202.

sculpture sometimes seen in *E. ovata* (Pl. II, fig. 33); but the bar-ornament of the latter is wanting.

E. Forbesii, though considerably larger, has much the same outline as some individuals of *E. minuta* (Pl. I, fig. 29); it has the same distinctness in its ridge-growth, and the same kind of ornament (the pattern being relatively smaller than that of the typical form, and scarcely larger than that of the Rhætic variety). Still, its much larger size, and its suborbicular form in the immature state, together with its occurrence in the other hemisphere, are sufficient to keep it specifically apart. The fact, too, that the reticulate ornament, but slightly modified, occurs on several modern as well as ancient species, must make us careful in applying it as a specific character either of alliance or distinction.

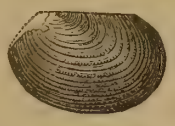
The geological position of the Estherian shale under notice is doubtful, and the *Estheria* itself affords no certain clue to its determination. The nearest ally (though sufficiently distinct) is *E. ovata* of the North American continent. Through possibly of Lower Mesozoic age, still the shale may belong to the Upper Mesozoic, or even to the Tertiary, period, so isolated is the place of deposit, and so manifold are the alliances of the animal, as far as the characters of the carapace are concerned.

14. Estheria Middendorfii, Spec. Nov. Pl. IV, figs. 12—22.

Height of valve..... $\frac{3}{6}$ inch
Length ..... $\frac{5}{6}$,, } Proportion 3 to 5, or 1 : $1\frac{1}{2}+$

Carapace-valves thin, suboblong, straight on the dorsal margin, nearly the whole of which is occupied by the hinge-line; umbo forward, not preserved in the many specimens seen; ends well rounded, and nearly equal; ventral margin gently and nearly symmetrically curved. Ridges distinct, about twenty-four, sometimes more numerous, and crowded towards the ventral edge; interspaces bearing an open, irregular reticulation (fig. 16), often passing into thin, transverse, somewhat irregular riblets (fig. 15); the irregularly hexagonal areas of the reticulation, when highly magnified, are seen to be delicately punctured (fig. 19).

Fig. 11.



Estheria Middendorfii, from Siberia. Natural size.

This fine *Estheria*, one of the largest known, occurs fossil in Siberia; it has been noticed by Dr. A. Th. von Middendorf (see further on). Most of the specimens that I have seen were brought to England by Mr. C. E. Austin, F.G.S., and are doubtless similar in every respect to those alluded to by Von Middendorf. They consist of a bluish-grey, finely laminated shale, slightly micaceous, indurated, fissile, and easily broken into irregularly shaped pieces. Some of the shale has the surface-planes of all the laminæ

thickly strewed with flattened carapaces of *Estheriæ*, accompanied with an occasional small Fish,[1] represented by a dark stain and the skeleton. In other specimens the Fishes are abundant, and the Crustaceans rare. Both valves of the carapace are in most cases present, and but little displaced; and sometimes what appear to have been the *ova* of the *Estheria* have left traces, in the form of small, globular grains. No other remnants of the organs of the animal have been discerned, although the thinness of the carapace, as delicate as the wing of an insect, would allow of such being seen. The valves have a light-brown colour, and are for the most part glossy along fine lines, corresponding chiefly to the concentric ridges, which present more solid, chitonous carapace-matter, whilst the finely reticulate interspaces do not reflect the light so readily. Frequently the valves are more or less crumpled with small, transverse wrinkles.

We have no finished sketch of *E. Middendorfii* on Pl. IV, on which the size of the valve is shown by fig. 12; the outline, magnified six times, for comparison with all the other Estherian valves figured on the same scale, is shown by fig. 13. The reticulated surface is shown on the lower part of fig. 16; the interior cast (on the shale) of that network is seen in the upper part of the same; the ova also are seen here, and more highly magnified in figs. 20, 21, 22. Fig. 17 is the natural cast of a reticulated interspace, somewhat resembling that in the lower part of fig. 16; fig. 14 is a similar cast of an interspace, having transverse riblets; and fig. 15 represents the ribbed interspace, restored by Mr. G. West, with setaceous ridges, that have left evidence of either setæ or rugæ in the specimen shown in fig. 14. Another natural cast of a reticulated interspace is given in fig. 18, but the clay has here replaced the raised network.

The first notice of *E. Middendorfii* is in Dr. A. Th. von Middendorf's 'Sibirische Reise,' Band i, Theil 1 ("Einleitung; Klimatologie; Geognosie"), 'Fossile Fische,' Bearbeitet von Joannes Müller,[2] p. 259, &c. Dr. Müller here describes the little fossil Fish, *Lycoptera Middendorfii* (which Sir P. Egerton informs me is probably an *Aspius*), together with a bivalved Crustacean, *Limnadia* (my *E. Middendorfii*). A larva of an Insect, probably neuropterous (neither *Ephemera* nor *Æschna*, but supposed to be possibly allied to both), and an obscure Paludina-like shell, were the only other fossils found in the Estherian shale. The Fish (figs. 1—5), the Crustacean (fig. 6), and the Larva (fig. 7), are carefully figured in pl. 11 of the work alluded to. At pp. 263 and 264 the shale and its locality are thus described by Von Middendorf:

"About 140 to 150 versts south of Nertschinsk, and some 70 versts from the nearest point of the Chinese frontier, a river named Byrka falls into the right side of the Turgá, at 40 versts above the confluence of the Turgá with the Onón, into which the Turgá also empties itself from the right. From the above-mentioned mouth of the Byrka downwards, a shaly clay forms the right bank of the Turgá, which has cut for itself a deep and pre-

[1] *Aspius* or some closely allied genus; according to Sir P. Egerton, Bart., F.R.S., &c.

[2] See also the 'Quart. Journ. Geol. Soc.,' vol. vi, part 2, "Miscell.," p. 45.

cipitous bed in the shale. At the depth of about a fathom from the surface the fossils are found in this shale. The Fish and Shells[1] occur throughout, and near one another, and not at all in separate beds; yet on the bank-cliff itself Shells occurred, but further inland Fish were laid bare by digging. The Crustaceans (*Limnadia*) are found, however, in another place of the said bank, evidently an ancient puddle of standing water. The shale is as yet not otherwise penetrated, but evidently extends to a great depth. The uppermost beds are, as it were, fatty, perhaps from the remains of decomposed Fish. About 40 versts southward from this place begin the wide, endless plains of the Mongolian Steppes. On the right bank of the Onón, at 30 versts upwards from the mouth of the Turgá, Fish-casts are also said to occur; according to the report of the Burats, there the shale is, as it were, pervaded with mica-flakes.[2]

M. E. d'Eichwald, of St. Petersburg, has favoured me with some pieces of this Siberian shale; he speaks of it as coming from near the village Tourtscha, on the banks of the Bibaya stream, which falls into the River Belaya, in the district of Nertschinsk.

Several specimens of this grey shale, containing Fishes and the interesting Entomostracans under notice, were presented to the Museum of the Geological Society in 1858 by Mr. Charles E. Austin, C.E., F.G.S., who collected them, in 1848, near Tourga (lat. about 51° 30′ N., long. 116° E.), from a cliff about 10 or 15 feet high, forming the western bank of the small stream Burká, flowing southward into the River Onón, at a distance of about 200 versts (about 133 miles) south-by-east from Nerchinsk, and between Tourga, Nerchinsk (or Nertschinsk), and Adoon-Zabor.

From information communicated by Mr. Austin I learn that on the bank of the stream, between the rising ground (above 100 feet high, formed chiefly of a gravel of augitic porphyry) and the stream, a shaft was sunk to examine the strata and to get specimens; and this penetrated—1st, some alluvium; 2nd, gravel of trap-rocks, with layers of soft clay and broken indurated shale, 2 feet 6 inches; 3rd, broken indurated shale, 1 foot 6 inches; 4th, white clay, 2 feet; 5th, slabs of the indurated fossiliferous shale in soft clay, 1 foot 6 inches; 6th, ferruginous clay, 1 inch. These beds seemed to dip westwardly at an angle of 25°. About 300 yards to the north of this spot, under a similar gravel, shale-beds, like the former, but unfossiliferous, intercalated with clay, 18 inches thick, and underlaid by 6 inches of rounded trap-detritus, are raised up and broken by a boss of basalt; these continue for some distance northwards in the bank of the stream, and ultimately disappear under a cliff of brown earth or volcanic tuff. On the eastern side of the stream is a plain, with outbursts of augitic porphyry, with asbestose serpentine, basalt, and greenstone, bounded by granitic hills running north and south, and

[1] Middendorf's term "Shells" here is equivalent to "Crustaceans" just below. He wrote this notice of the locality after Müller had recognised the Crustacean character of what he had previously been used to look upon as molluscs. Besides, there were no real shells found except the obscure *Paludina*.

[2] It is to be remarked that almost all the known Estherian marls, shales, or mud-stones, are more or less micaceous, and therefore formed in quiet waters, where currents have ceased.

associated with lava and scoriæ, and granite rich in garnet, yellow topaz, and aqua-marine. Mr. Austin thinks that the shale-beds formed the surface at the time of the last igneous eruption of any magnitude in that part of Siberia, and that it was then disturbed and covered by the volcanic products. He noticed in the shale, besides the Fishes and Crustaceans, one spiral shell (*Limnæa* or *Paludina?*), several impressions of stems and reed-like plants, and a small rhomboidal piece of lignite; but nothing more definite can be at present said of the age of the deposit than that it is probably of Tertiary age, and of freshwater origin.

Mr. W. Davies, of the British Museum, informs me that *Aspius* (such as accompanies *Estheria Middendorfii*, see above, p. 112) was a true freshwater fish, of the Cyprinoid family, and closely related to *Leuciscus*, differing from the latter genus in having a more compressed body, and a more slender skeleton. The species are found in Miocene Tertiaries, as the freshwater limestone of Œningen and the lignites of Menat, &c.

Note.—Although the Purbeck specimens hitherto supposed to be Estherian are Archæoniscal (see p. 105), yet there are real Purbeck *Estheriæ;* for Mr. Harry Seeley, F.G.S., of the Woodwardian Museum, Cambridge, informs me to-day that an *Estheria*, "very like the Hastings species, has just been detected in the Lowest Purbeck beds near Swanage."—*December* 17, 1862.

[*To face page* 114.

GEOLOGICAL STAGES.	BRIT	CA.	SOUTH AMERICA.	ESTHERIÆ.
TERTIARY	.....	.....	.....	*Estheria Middendorfii* (?).
CRETACEOUS.[1]				
WEALDEN	Sussex. H	.....	.....	*Estheria elliptica*, and *E. elliptica*, var. *subquadrata*.
JURASSIC	Oxfordian,	.....	.....	*Estheria Murchisoniæ*, *E. concentrica*, and *E. Kotahensis*.
	Lower Ooli			
RHÆTIC[2]	Linksfield,	stern	Cacheuta	*Estheria minuta*, var. *Brodieana*, *E. Mangaliensis* (?), *E. ovata* (?), and *E. Forbesii* (?).
	Warwicksh	Jorth		
	Glouceters			
	Somersetsh			
TRIAS	Leicestersh	.....	.....	*Estheria minuta*.
	Warwicksh			
	Worcesters			
	Somersetsh			
PERMIAN	Rhone Hil	.....	.....	*Estheria Portlockii*, *E. tenella*, and *E. exigua*.
CARBONIFEROUS	Upper Coa Manches	.....	.....	*Estheria tenella* and *E. striata* and its varieties.
	Coal-meas and Lan			
	Lower Car wickshir			
	[*Leaia*[3] occu			
	Coal-meas shire, and ferous of I	Lower Penn-		
OLD RED SANDSTONE	Caithness	.....	.....	*Estheria membranacea*.

[1] No fossil *Estheria* are as yet re siberian and the South American *Estheriæ* described above being of this age.

[2] The adoption of this stage for

[3] See the Appendix.

TABLE SHOWING THE DISTRIBUTION OF THE FOSSIL ESTHERIÆ.

[To face page 114.

GEOLOGICAL STAGES.	EUROPE.				ASIA.		NORTH AMERICA.	SOUTH AMERICA.	ESTHERIÆ.
	British Isles.	France and Belgium.	Germany.	Russia and Baltic Provinces.	Siberia.	India.			
Tertiary					Tourga (age doubtful)				*Estheria Middendorfii* (?).
Cretaceous.[1]									
Wealden	Sussex. Purbeck (?)		Hanover						*Estheria elliptica*, and *E. elliptica*, var. *subquadrata*.
Jurassic	Oxfordian, Skye; Lower Oolite, Scarborough					Kotah, on the Pranhita			*Estheria Murchisoniæ*, *E. concentrica*, and *E. Kotahensis*.
Rhetic[2]	Linksfield, Elgin; Warwickshire; Gloucestershire; Somersetshire					Mangali and Pancheet	Pennsylvania, Eastern Virginia, and North Carolina	Cacheuta	*Estheria minuta*, var. *Brodieana*, *E. Mangaliensis* (?), *E. ovata* (?), and *E. Forbesii* (?).
Trias	Leicestershire; Warwickshire; Worcestershire; Somersetshire	Sulzbad	Hanover and Würtemberg						*Estheria minuta*.
Permian	Rhone Hill, Tyrone		Lower Permian, Saxony	Kargala, &c.					*Estheria Portlockii*, *E. tenella*, and *E. exigua*.
Carboniferous	Upper Coal-measures, Manchester; Coal-measures, Derbyshire and Lanarkshire; Lower Carboniferous, Berwickshire	Permian (?) or Upper Carboniferous (?), Autun; Lower Carboniferous, Belgium	Permian (?) or Upper Carboniferous (?), Murgthal; Lower Carboniferous, Silesia and Bavaria						*Estheria tenella* and *E. striata* and its varieties.
	[*Leaia*[3] occurs in the Upper Coal-measures of Lancashire, and Lower Carboniferous of Fifeshire]						[*Leaia* occurs in the Lower Carboniferous of Pennsylvania.]		
Old Red Sandstone	Caithness and Orkney			Livonia					*Estheria membranacea*.

[1] No fossil *Estheria* are as yet referred to this period, excepting those of the Wealden formation (representing some of the freshwater deposits of the period). There is, however, the possibility of either or both of the Siberian and the South American *Estheriæ* described above being of this age.

[2] The adoption of this stage for the *Estheriæ* from India and America is merely provisional; they may be Triassic.

[3] See the Appendix.

APPENDIX.

LEAIA, Gen. Nov.

I HAVE proposed the above name as a generic denomination for certain peculiar, quadrate, bivalved carapaces, occurring in the Coal-measures of Britain and the Lower Carboniferous red sandstone of Pennsylvania. I know nothing of their nature except that they are small, thin, horny, brown, stiffly quadrate, symmetrical bodies, unlike Molluscan shells, but possibly Crustacean and Phyllopodous.

I have some specimens from the Upper Coal-measures of Ardwick, near Manchester (collected by Prof. Williamson, F.R.S., several years since); and some from the Lower Coal-measures of Fifeshire, collected by Mr. Salter, F.G.S., of the Geological Survey. Dr. Isaac Lea described and figured, a few years ago, a similar fossil from the red sandstone of Pennsylvania, and named it *Cypricardia Leidyi*. All these three are very much alike; but, on account of the obscurity of their relationship, and the distant places, geological and topographical, of their occurrence, and making the most of their slight differences of contour, I propose to keep them nominally distinct as *Leaia Leidyi* (Pl. V, figs. 11, 12), *L. Leidyi*, var. *Williamsoniana* (Pl. I, figs. 19, 20), and *L. Leidyi*, var. *Salteriana* (Pl. I, fig. 21). Dr. I. Lea, of Philadelphia, being the first to notice and figure a specimen of this proposed genus, I have distinguished it by a name commemorative of that well-known conchologist.

The carapace-valves are oblong; truncate behind, with a slight curvature of outline; boldly rounded in front; either straight or somewhat curved on the ventral border; straight on the dorsal edge; a slight umbo takes the place of the antero-dorsal angle, from whence two conspicuous ridges (hollow within) pass along the surface of the valve; one directly across the valve to the antero-ventral angle; the other, and longer one, passes diagonally to the postero-ventral angle; these ridges divide the convexity of the valves into three, unequal, triangular, smooth, sloping areas; the anterior space is the smallest and nearly semicircular; the middle one has its apex at the umbo and its base along the

ventral margin; and the posterior space is based on the hinder margin, and reaches along the dorsal region to the umbo. The surface of the valve is marked with 10-13 (?) delicate ridges (hollow within), concentric, beginning at the umbo, conformable to the outline of the valve, and sharply bent at the divergent ridges; they are curved and closely set on the anterior area; more open, horizontal, and straight, or nearly so, on the middle area; and vertically straight or slightly curved, and wider apart, on the posterior part of the valve.

These symmetrical markings of concentric angular lines and transverse divergent ridges give this fossil, at first sight, a striking likeness to some Fish-scales, when the two valves lie open, in contact by their dorsal edges (as in Pl. I, fig. 19), and produce a bilaterally symmetrical, subquadrate, concentrically lined figure, with triangular sloping areas.

Dr. Lea points out some *Cypricardiæ* and other shells of palæozoic age to which this little fossil has some resemblance in shape; and some *Orthonotæ* have a general resemblance to it; but some of the small *Astartes* of the Chalk and Oolite, such as the *A. Roemeri*, Müller's Petref. Aachen. Kreideform., Pl. 6, fig. 12, and *A. interlineata*, Morris and Lycett, Mollusca of the Great Ooolite (Palæontogr. Soc. Monograph), Pl. 9, figs. 14, 15, have even a greater resemblance in size and shape, without being at all allied to the form before us.

The horny tissue of *Leaia*,—its long dorsal edge, destitute of hinge,—its stiff and simple style of ornament,—and its two diagonal, raised, hollow ridges or folds, remove it from the *Mollusca*. It has been suggested (by Phillips and Williamson) that these fossils may be *Trigonellites* (of *Goniatites*?); but there is little or nothing to support the hypothesis.

LEAIA LEIDYI, Lea, sp. Pl. V, figs. 11, 12.

CYPRICARDIA LEIDYI, *Lea*. Proceed. Acad. Nat. Sc. Philadelphia, 1855, vii, p. 341. pl. 4.

Height of valve, nearly $\frac{3}{2^4}$ inch
Length „ nearly $\frac{5}{2^4}$ „ } Proportion 7 to 12, or 1 : $1\frac{3}{4}$ —

In the 'Proceedings Acad. Nat. Science of Philadelphia,' May, 1855, vol. vii, p. 341, Dr. I. Lea has described a small fossil found by Dr. Leidy in a red sandstone at Tumbling Run Dam, about a mile south-east of Pottsville in Pennsylvania. The specimen consists of the impression of the outside of the two valves. It is figured carefully, of natural size, and enlarged, in plate 4 (op. cit.[1]), and is named *Cypricardia Leidyi*, by Dr. Lea, who thus describes it:

"Shell oblong, round before and truncate behind, very inequilateral, striate; dorsal and basal margins parallel; umbonal slope shortly carinate; anterior slope with an

[1] By inadvertence, the enlarged view is stated to be magnified 10 instead of 5 times.

elevated line from the back to the basal margin; striæ about twelve, very regular, and nearly equidistant (bent at an angle of 90° at the umbonal slope). Length, $\frac{2}{10}$ths, breadth, nearly $\frac{1}{10}$ths of an inch." "The shell is accompanied on the specimen with some obscure impressed linear marks of a plant."

The figures are reproduced here (Pl. V, figs. 11, 12). The sandstone is referred to the formation called No. XI by Prof. H. D. Rogers in the State Geological Survey of Pennsylvania, and referred by him to the base of the Carboniferous system, but regarded by some geologists as the uppermost part of the Devonian or Old Red Sandstone. In this formation of sandstone (which, with its associated shales, is 3000 feet thick), Foot-tracks of Reptiles, Rain-prints, Wave-marks, and Trails of Annelids or Molluscs are not uncommon[1] at two or more horizons.

LEAIA LEIDYI, var. WILLIAMSONIANA. Pl. I, figs. 19, 20.

BIVALVULAR SHELL?, *W. C. Williamson.* Philos. Mag., new series, 1836, ix, p. 351.
APTYCHUS?, *J. Phillips.* Silur. Syst., 1839, p. 89.

Inch.			Inch.		
Height of valve ...	$\frac{1}{16}$	Proportion 1 to 2.	Height	$\frac{5}{9\,6}$	Proportion 5 to 9, or 1 : 2—
Length	$\frac{1}{8}$		Length	$\frac{9}{9\,6}$	

This is very like *Leaia Leidyi;* but, as it is much smaller, and appears to be still neater in form, and to have a few more striæ, and as it comes from the much higher horizon of the Uppermost Coal-measures, and in England, I propose to treat of it separately, as a variety under the above name, which will associate it with its well-known discoverer, Prof. Dr. W. C. Williamson, F.R.S., of Manchester.

The specimens lie dispersed in a soft grey shale, in considerable numbers, and are not disposed on the planes of bedding. They are from the Uppermost Coal-measures of Lancashire (Ardwick, near Manchester), and were confided to me for examination, in 1856, by Prof. Williamson, who believed them to belong to some nondescript Entomostracan, if they should not prove to be *Trigonellites.* He found them many years ago, and referred to them in a paper (on the Limestones found in the vicinity of Manchester) published in 1836 in the 'Philos. Magaz.,' new ser., vol. ix., from which the following extract has been taken.

"In the blue clay immediately above the 'black bass' are a series of remains, in attempting to decide upon the nature of which I find myself completely puzzled. They are very thin bodies of a brown colour, nearly square in their form, two of the corners

[1] See 'Boston Soc. Nat. Hist. Proceed.,' vol. v. p. 182, and Lyell's 'Manual of Geology,' 5th edit., p. 379, &c.

being angular, and the opposite one rounded. I have some nearly a quarter of an inch across. At first I imagined that these were scales of fish, but now think they must be some bivalvular shell. Their surface is marked with strong concentric ridges; and passing from the hinge (?) to the opposite corners are two diverging elevated lines. I cannot detect any traces of teeth; but have found several specimens in which the two valves (?) were connected at the hinge, and the four ridges commencing from one common point in the centre, and diverging two each way; these I pointed out to Prof. Phillips, who will, perhaps, be able to lay before the public some more decided opinion as to their nature[1]" (p. 351).

At page 245 of the same paper, Prof. Williamson gave a section of the strata at Ardwick, which will serve to illustrate the exact position in which these curious little fossils were found. The section[2] is as follows:—the fossils mentioned in the paper as peculiar to the beds being inserted in their places.

	Feet.	Inches.
Red clays with sandstone (*Unio Phillipsii*[3] in one thin seam), thickness not known.		
Limestone. "Four-feet Mine." (*Megalichthys Hibberti* in the roof. *Microconchus.*)	4	0
Red and blue clay. "Clunch."	6	0
Coarse micaceous grit	6	0
Clunch	6	0
"Roof-stone;" a shaly sandstone	0	3
Limestone. "Yard Mine." (*Microconchus.*)	3	0
Clunch	5	0
Limestone (fragmentary shells in the upper portion: *Unio* ?)	2	0
Clunch and shaly clay	17	0
Limestone	1	0
Red shale. (*Asterophyllites, Calamites decoratus, C. nodosus, Lepidodendron Sternbergii, Stigmaria ficoides, Neuropteris cordata, Cyclopteris, Pecopteris*)	15	0
Limestone	1	6
Coloured clays	45	0
Blue clay. (*Entomostraca* [*Leaia*], *Unio Phillipsii, Sphenophyllum, Pecopteris, Equisetum.*)	1	0
"Black bass:" pyritous shale. (*Unio Phillipsii, Cypridæ*, Fish-remains.)	1	0
Coal. (*Stigmaria ficoides.*)	0	6

[1] Professor Phillips referred to these little fossils in the 'Silurian System,' p. 89 (1839) and suggested that they may be *Aptychi* (*Trigonellites*).

[2] The place of these strata in the general section of the Manchester district is shown in Mr. Binney's paper, 'Trans. Manchester Geol. Soc.,' vol. i, p. 50, pl. 1, fig. 1.

[3] Prof. Phillips terms this shell *U. linguiformis* ('Sil. Syst.,' p. 88); Mr. Binney thinks it may be a *Modiola* ('Manchester Lit. Phil. Soc. Mem.,' vol. xii, p. 221); and Mr. Salter regards it as an *Anthracomya*.

	Feet.	Inches.
Blue clay, sometimes red	5	0
Limestone. Main seam or "Three-yards Mine." (Fish-remains. *Microconchus.*)	9	0
Coloured shaly clays.....about	60	0
Coal	1	3

Coloured clays.[1] Thickness not known.

LEAIA LEIDYI, var. SALTERIANA. Pl. I, fig. 21.

Height of valve, more than ... $\frac{1}{24}$ inch
Length „ less than ... $\frac{3}{24}$ „
} Proportion 7 : 17, or 1 : $2\frac{1}{2}$ —

Some specimens of *Leaia*, resembling both *L. Leidyi* and *L. Leidyi*, var. *Williamsoniana*, in general appearance, but relatively shorter, broader, more strongly ridged, more quadrate, and somewhat more rounded on the ventral and posterior borders, have been placed in my hands by Mr. J. W. Salter, F.G.S., of the Geological Survey of Great Britain. They are from the Lower Carboniferous rocks of Fifeshire, Scotland; and, on account of their differing (though slightly) from the other two forms, and on account of their distant locality and different geological horizon, I shall regard them as belonging to a distinct variety, and give it Mr. Salter's name, to whom I am indebted for the knowledge both of these and very many other palæozoic *Entomostraca*.

These specimens of the variety *Salteriana* are somewhat numerous in a fine-grained, hard, light-brown, clay-iron-stone, from Cottage-Row, Crail, Fife; and are dispersed through the stone; about twenty-two are to be seen on five square inches. They are associated, I am informed by Mr. Salter, with *Lepidodendron* and *Lepidostrobus;* and the stratum in which they occur is intercalated between beds full of Brachiopods, together with *Myalina* and *Anthracosia*. Mr. Salter says that similar beds occur in the district, containing *Amblypterus* and *Rhizodus*, with *Cythere* (or *Cytheropsis*) *Scotoburdigalensis*. For an account of the section of the Carboniferous strata of the Fifeshire coast, see the Rev. T. Brown's Papers in the 'Quart. Journ. Geol. Soc.,' 1859, vol. xv, p. 59, and 'Transact. R. Soc. Edinb.,' 1861, xxii, p. 385.

Habitat of Leaia.—The *Anthracomyæ* associated with *Leaia Leidyi*, var. *Williamsoniana*, are probably evidences of at least a brackish condition of the water in which this Crustacean existed.

[1] In the section of the strata at Manchester, given in the 'Silurian System' (1839), p. 87, instead of "clays" at the base, we have "grit or great red rock, with micaceous marls and *Unionies*, 81 feet," and a long list of still lower strata. This section, based on that of Prof. Williamson, and corrected by Prof. J. Phillips, has some discrepancies with the older one, and its plan of classification differs from that adopted by Messrs. Williamson and Binney. All the limestones, however, I believe, are now regarded as belonging to the Carboniferous system; and Prof. Williamson's original section very well indicates the exact place of the *Entomostraca* under notice. Prof. Phillips's account of the fossils from the sections at Ardwick ('Sil. Syst.,' p. 88, 89) necessarily deserves attention.

Notes on the Beyrichiæ and Cypridæ associated with the Fossil Estheriæ.

Occurring with *Estheriæ,* in deposits of different ages, both Palæozoic and Mesozoic, are several small Bivalved Entomostracans, belonging, for the most part, to the *Lophyropoda;* Tribe, *Cyproidea;* Family, *Cypridæ.*[1] A few other *Entomostraca* are associated with some of the Palæozoic *Estheriæ;* and these belong probably to the *Phyllopoda;* Tribe, *Limnadioidea;* Family, *Leperditidæ.*[2]

As it is highly desirable to get as much information as possible respecting the habitats of fossil *Estheriæ,* I determined not to neglect the associated Entomostracan remains; and have, therefore, figured them in Pl. V, and will proceed to describe them: but, with our present knowledge of them and their alliances, they throw but little additional light on the subject. In fact, it is difficult to assign most of them to their sub-families and genera, so similar are the carapaces of some generically distinct *Cypridæ.*

1. Beyrichia subarcuata, spec. nov. Pl. V, figs. 16, 17.

Length, $\frac{1}{22}$ inch. Height, $\frac{1}{45}$ inch.

Carapace-valves elongate-reniform, the length nearly double the height (or breadth); indented at the middle of the dorsal border by a short, transverse notch, reaching about one fourth across the valve, and by another still slighter notch at rather less than half-way between the larger notch and the anterior (?) end of the valve. The surface is delicately reticular, with minute hexagonal pits (fig. 17).

This *Beyrichia* feebly represents the well-lobed Silurian forms of this genus: it is very closely allied to *B. arcuata,* Bean, sp. ('Mag. Nat. Hist.' 1836, vol. ix, p. 377, fig. 55). Indeed it may ultimately prove to be a variety of this species, which is very common in the Coal-measures. *B. subarcuata* occurs with *Estheria tenella* in the Upper Coal-measures at Astley, Lancashire (see page 32); and, if this species had the same habits as the older *Beyrichiæ,* it speaks of marine conditions; at all events we may regard it as at least having a brackish habitat.

[1] See the Synopsis of the *Crustacea,* at p. 10.

[2] This is the grouping which I have proposed for *Beyrichia* and its allies ('Annals Nat. Hist.,' Feb., 1856, p. 99), the carapace alone being considered.

2. Beyrichia Pyrrhæ, *Eichwald*, sp. Pl. V, figs. 18, 19.

Cypris Pyrrhæ, *Eichwald*. (The name only is given in Jazykov's Table of the Formations of the Government of Simbirsk, published by the Petersburg. Mineral. Geselischaft, 1844, according to Von Keyserling.)

Cytherina Pyrrhæ,[1] *Eichwald*. Geogn. Russl.,[2] 1846, p. 466. Bullet. Soc. Imp. Nat. Moscou, année 1857, vol. xxx, 2nd part, 1857, p. 307.

Bairdia Pyrrhæ, *Eichwald*. Lethæa Rossica, 7th part, 1860, p. 1344, pl. 52, fig. 3 *a*, *b*.

Length of the figured specimen, $\frac{1}{28}$ inch.[3] Height, $\frac{1}{45}$ inch.

Carapace-valves oblong-ovate; extremities nearly equal, the posterior being rather larger than the other; upper margin straight, curved symmetrically at the ends; dorsal region faintly impressed by two short, shallow, transverse indentations, which obscurely divide that part of the valve into three nearly equal parts. The anterior sulcus is the more distinct of the two. A slight, neat, flattened border follows the curved margin of the valve. The surface is beautifully reticulated with minute hexagonal pits (fig. 19).

M. d'Eichwald correctly describes this little fossil as follows, excepting that he omits the ornamentation and the rim, and regards the faint dorsal elevation as due to the internal attachment of the muscle :—"Testa exigua, tenuissima, plana, ovato-dilatata, uno latere latiore altero, utroque rotundato, tuberculo sive eminentia musculari prope marginem dorsalem obvia, foveolam utrinque præ se ferente, oculo non conspicuo." He remarks that the anterior sulcus is more constant than the other, and that some individuals have a more rounded outline than others, and do not show the dorsal protuberance. In the figure given in the 'Lethæa Rossica' the dorsal notches are more distinct than they are in our specimen.

This little Entomostracan has no family-relationship to the *Cypridæ*, and least of all to the sub-genus *Bairdia* in particular. Its general features and its dorsal notches show it to be a *Beyrichia*, though with feeble characters of carapace. Indeed, we may have ultimately, for convenience of grouping, to separate the simpler forms from those with many-lobed carapaces, however gradual may be the stages of difference. Further, the species before us presents an interesting passage-form between the simple *Beyrichiæ* and the non-sulcated carapaces known as *Cytheropses*.[4] The amount of sulcation in *B. Pyrrhæ*

[1] *Cythere Pyrrhæ* (?), Keyserling, in Schrenk's 'Reise,' &c., 1854, p. 112, pl. 4, fig. 41, is *C. ovata*, Eichwald. See 'Bullet. Soc. Imp. Nat. Mosc.,' 1857, p. 308; and Eichwald's 'Leth. Ross.,' p. 1344.

[2] Published in the Russian language.

[3] M. d'Eichwald has described specimens having the dimensions of 1 by $\frac{1}{4}$th line.

[4] Compare *Cytheropsis concinna* (?), 'Annals Nat. Hist.,' April, 1857, p. 254, pl. 9, fig. 3.

evidently varies very much, being sometimes obsolete; indeed, at first I thought to class it with *Cytheropsis* (see above, p. 38, *note*).

Beyrichia Pyrrhæ is very abundant in the greyish marl of the Permian formation near Burakova, in the government of Kazan, and occurs here in company with *Estheria exigua* (*Cytherina Eos*, Eichw.), see pp. 38 and 40.

In treating of the following *Entomostraca* I have much hesitation in assigning them to definite genera and species, as their hinge-lines and other specialities are, for the most part, unknown. Figs. 13 to 15, 20 to 25, and figs. 31 to 34 may be either *Cytheres*, *Cyprides*, or *Candonæ*, and there are but few distinctive features among them, whether they be of Carboniferous age (figs. 13, 14, 15), of Rhætic (figs. 20—24), of Jurassic (fig. 25), or of Wealden (figs. 31—34); amongst these last, tangible differences are best seen. Comparing figs. 13 and 14 with figs. 20 and 21, we see similar-looking carapace-valves from the Coal-measures of England and the Lower Mesozoic deposits of Virginia; and, allowing for the possible effects of pressure and imperfection of the margins of the valves, it is somewhat hazardous to attempt to define their specific characters. A glance at Plate I and Plate IV of my 'Monograph of the Tertiary Entomostraca of England,' 1856, will give an idea of the recent and tertiary forms that most closely resemble those under consideration. Among those referred to, however, *Candona* (of freshwater habitat) is the genus which supplies the chief analogies; and as the habitats of *Estheriæ* seem to me to have been mostly freshwater, the associated fossil *Cypridæ* may be provisionally referred to *Candona*. I do not, however, deny that some of them may have been *Cytheres* (but even then they may have affected fresh or brackish water); nor that, being *Candona*, they may not have been able to live in saltish water (as *Cypridæ* do occasionally, see above, p. 8).

The following *Cypridæ* are figured with what appears to be the anterior extremity upwards; and the more convex of the two long margins is regarded as the dorsal.

3. Candona (?) Salteriana, sp. nov. Pl. V, figs. 13, 14.

Length, $\frac{1}{19}$ inch. Breadth, $\frac{1}{45}$ inch.

Carapace-valve smooth, elongate-oval, with nearly straight ventral and dorsal margins. Fig. 13 has both extremities somewhat obliquely curved; fig. 14 has one end nearly semicircular; and this was probably the natural condition, as is usual in this group. The antero-dorsal slope in fig. 14 may have been exaggerated by pressure. This Cyprid is, in size, intermediate between *Candona Forbesii* and *C. Richardsoni* of the Eocene deposits ('Tert. Entom.,' p. 18, pl. 4, figs. 8—12). Although little is known about it, yet it is advisable to give it a distinguishing name; and none can be better than one derived from

the ardent palæontologist who found it and introduced it to me, who has so carefully studied the fossils of the Coal-measures, and who has contributed so much to the materials of this Monograph.

Candona (?) *Salteriana* occurs in the shales of the Four-foot Coal, Bradford Pit, near Manchester (see page 32). These belong to the Upper Coal-measures, and contain, besides *Estheria tenella*, a shell named *Unio Phillipsii* by Prof. Williamson, but now regarded as an *Anthracomya* by Mr. Salter, and remains of *Lepidodendron Sternbergii*.

4. Candona (?) Tateana, sp. nov. Pl. V, fig. 15.

Length, $\frac{1}{48}$ inch. Breadth, $\frac{1}{90}$ inch.

A small, smooth, oval carapace-valve, somewhat crushed, occurs with *Estheria striata*, var. *Tateana*, at Lammerton, Berwickshire (see p. 27). This, for the sake of distinction, though it is but poorly defined, may be denominated *Candona* (?) *Tateana*, after the enthusiastic geologist to whom we are indebted for its discovery.

North American Lower Mesozoic Cyprida.

In the numerous notices of the Estherian and Carbonaceous shales of Pennsylvania, Virginia, and North Carolina, by the State-geologists and others, to which reference is made in the account of *Estheria ovata* given above (pp. 84—99), frequent mention is made of the *Cyprida* found in some of those shales. These have been generally termed "Cyprides," and sometimes "Cytheres" and "Bairdiæ" (Emmons). As they have come under my observation whilst studying *Estheria ovata*, I now proceed to describe them by the help of specimens kindly submitted to me by the Professors W. B. and H. D. Rogers and Mr. Wheatley. For the same reasons that I assigned the above-described Cyprid from the English Coal-measures to the recent genus *Candona* (with some doubt), I here refer the very similar North American Mesozoic forms to the same genus, but with less hesitation, as the carapace is better preserved; and, from their general features and habit, I have no doubt that they are either *Cypris* or *Candona*, most probably the latter. There appear to be two species, one having a smooth, the other a pitted, carapace; and this distinction we may provisionally accept as specific until we find individuals occurring partially punctate or otherwise intermediate in character.

5. Candona (?) Rogersii, sp. nov. Pl. V, figs. 20, 21, 22.

Cypris, *W. B. Rogers.* Proceed. Boston Soc. Nat. Hist., 1854, vol. v, 15.
— *J. Leidy.* Proc. Acad. Nat. Sci. Phil., June 16, 1857, p. 150.
— *Wheatley.* Amer. Jour. Sci. Arts, 2nd ser., 1861, vol. xxxii, p. 42.
Bairdia, Cypris, } *Emmons.* American Geology, part vi, 1857, pp. 39 and 56.

Length, $\frac{2\frac{1}{2}}{72}$ inch. Breadth, $\frac{1}{72}$ inch.

Carapace-valves smooth, oblong, rounded at the extremities, but narrower and obliquely rounded anteriorly; ventral margin straight, dorsal slightly arched; hinge-line simple, as in *Candona*. It is difficult to find a well-preserved and well-exposed specimen on the shales. Fig. 21 is slightly deformed by pressure on the dorsal curves. Fig. 22 is a cast of a narrowish or compressed carapace; were it broader, it would better represent the common typical form. Fig. 20 is a young individual. The two figured specimens correspond with the two figured by Dr. Emmons in his 'American Geology,' part VI, p. 39, fig. 10. A slight, flat, marginal rim is often apparent, except on the anterior border (fig. 21).

This is very similar to fig. 14, excepting in size; but the very great difference in geographical and geological position weighs with me in supposing that this may be specifically distinct from its Palæozoic and European analogue on one hand, and from its Eocene analogues (*C. Forbesii*, &c.) on the other. As it is an abundant fossil in the Lower Mesozoic Estherian shales of Virginia and North Carolina, and present in those of Pennsylvania, it is well that it should have a distinct name, and none can be better than one derived from the two eminent brothers who have worked so well on the geology of those regions.

The chief specimens that I have seen (lent to me by Messrs. Rogers) are from Virginia (Culpepper County, and Prince Edward, near Richmond) and from North Carolina (Deep River). Those from near Richmond are in black carbonaceous shale; the valves are numerous on the bed-planes, single, smooth, thin, calcified, and more or less crushed, varying in length from 1-24th inch downwards; the smaller ones appear to be less tapering at the anterior end than the other; but they are all, I have no doubt, of the same species. Those from Deep River are in a similar black shale, and altogether like those from Richmond above described; and there are traces of *Estheria*[1] amongst them. The specimens from Culpepper Co., Virginia, consist of casts and moulds crowded in red shale (on bed-planes), associated with *Estheria*.

I have also met with this smooth *Candona* (?) in the Pennsylvanian shales which were

[1] These fragmentary *Estheria* certainly appear to be *E. ovata*, and so far supply the wanting link in my argument respecting the specific identity of the *Estheriæ* from the several localities. (See p. 91.)

sent to me by Mr. Wheatley (see above, p. 93), particularly in a hard red shale. It appears, however, to be rare in some of these shales, for in a black shale, showing the *Cypridæ* in good preservation, there are but one or two of these associated with a multitude of the pitted *Candona* (*C. Emmonsii*). Some of these Estherian and Cypridiferous shales from Phœnixville, however, are largely made up of indistinguishable *Cypridæ*, and the smooth form may be abundant enough in several of the beds.

Dr. E. Emmons, in his 'American Geology,' part VI, notices the abundant occurrence of these *Cypridæ* "in the Chatham series of Deep and Dan Rivers;[1] they are also abundant in the black shales of Halifax County, Va., in the same geological position" (p. 39). This author terms some of them "Bairdiæ:"[2] but they certainly do not belong to that sub-genus of *Cythere;* and the "lobulated" condition of the valves, as described and figured by him (figs. 10 and 11, pp. 32, 40), is due merely to crush and fracture; others he seems to think may belong to *Cypris*[3] (pp. 39 and 54). He also observes that these "minute Crustaceans frequently fill entire strata. The individuals are about 1-30th of an inch long. They have the form of a bean, and their carapaces are smooth. They differ in size; some are about half the length of the largest, and appear to be equally numerous with the larger. They are numerous in all the upper part of the black shales.[4] About seventy feet above the coal-seam they become rare, and, indeed, I believe, are not to be found below the level" (p. 39). "They do not exist at all in the immediate vicinity of the coal-seams" (p. 40). They are abundant in some strata and absent in others.

In the "Upper Red Sandstone and Marls (Keuper), Chatham Co., North Carolina, about seven miles south of Egypt [Deep River, North Carolina], there are Cyprides also, which are quite numerous upon certain soft red layers" (p. 134).

6. Candona (?) Emmonsii, sp. nov. Woodcut, fig. 12.

Cypris; granulated species (?), *Rogers*. Proceed. Boston Soc. Nat. Hist., vol. v, p. 15.
— „ *Wheatley*. Amer. Jour. Sci. and Arts, 2nd ser., 1861, vol. xxxii, p. 44.

Length, $\frac{1}{36}$ inch. Breadth, $\frac{1}{72}$ inch.

In one of the hard black shales sent from Phœnixville by Mr. Wheatley is a layer of *Cypridæ*, well preserved, their interior being filled with calcite, and their convex crusts retaining perfect shape, and showing a neatly punctate surface, marked with minute sub-

[1] See above, p. 90.

[2] Because he regards the formation to be either marine or brackish, and because he supposes the valves to have the hinge-joint of *Bairdia*.

[3] At p. 31 Dr. Emmons, it seems, refers all these Entomostracans to *Cythere*.

[4] See the section of the black shales at Egypt Pit, Deep River, p. 89.

hexagonal pits, with something like the pattern of the outside of a thimble, an ornament common among bivalved Entromostracans. These specimens, though numerous, are scarcely ever clearly exposed out of the matrix on all sides, so it is difficult to get at their real outline, which seems to be just that of *C.* (?) *Rogersii*. (See woodcut, fig. 12.)

Fig. 12.

Candona (?) Emmonsii, *from Pennsylvania. Magnified* 30 *diameters.*

One, and perhaps two, of the last-named species occurs on the same block, but in a different layer. As is the case sometimes with *C. Forbesii*, these carapaces lie crowded together, for the most part parallel or nearly so one with another, a circumstance due, perhaps, to the action of a slight current in the water at the bottom of which they were deposited.

This is probably the so-called "granulate" species referred to by Rogers and Wheatley (see above, p. 94).

What I have stated at pp. 91 and 92 respecting the probability of the chief Estherian and Carbonaceous shales of North Carolina, Virginia, and Pennsylvania, being on one geological horizon, and of the upper Estherian shales of Deep River being of essentially the same age, though separated from the others by upwards of 1800 feet of bedded rocks,[1] will apply to the *Cyprida* now under notice.

Whether or not these deposits have a Keuperian character, as Prof. O. Heer's late determination of the Coal-plants from Richmond, Va., seems to indicate, there is no doubt of their being the products of lagoons in the Lower Mesozoic period, and contemporary either with the marine formation intermediate to the Trias and Lias,[2] namely, the Rhætic, or with the Upper Trias itself, and exactly equivalent to the Letten-Kohle[3] (carbonaceous shales at the base of the Keuper).

7. Candona (?) globosa, *Duff*, sp. Pl. V, figs. 23, 24.

Cypris globosa, *Duff*. Geology of Moray, 1842, p. 16.

Length, $\frac{1}{50}$ inch. Breadth, $\frac{1}{60}$ inch.

Carapace sub-cylindrical, smooth; carapace-valves oblong, straight on the ventral edge, slightly arched on the dorsal, rounded at the ends, but obliquely at the antero-dorsal region, so that the fore end is narrower than the other. Lucid spots (muscle-mark) apparent, like those of *Candona Forbesii* ('Monog. Tert. Entom.,' p. 18).

[1] Usually regarded as of that *vertical* thickness (see *note*, p. 91).

[2] The coal-beds of Steierdorf, Banat, appears to belong either to the Lower Lias or the Rhætic formation.

[3] See above, pp. 46, 49, &c. I am strongly inclined to coincide with Mr. Hislop in his views as to the age of the beds in India that have yielded *Estheria Mangaliensis* (see p. 78), and to regard them as "Upper Triassic" (p. 79), instead of "Rhætic" (p. 81), if we must find an exact European equivalent for them.

This must be the Cyprid referred to by Mr. Duff in his description of the shales at Linksfield, where *Estheria minuta*, var. *Brodieana*, occurs (see above, p. 67). Although the trivial name is not the best that could be found for it (as its oblong form hinders its convexity from making it globose), yet I will not interfere with the name given by its first observer.

This Rhætic *Candona* is very like the Tertiary *C. Forbesii* and other closely allied forms, including the Mesozoic *C. Rogersii* and the recent *C. reptans*, its relative size and proportions making but little real distinction. It is well, however, that it should have a distinctive name for convenience of geological grouping.

C. globosa occurs in great numbers, and in many laminæ, in the greyish calcareous shale or marl at Linksfield; and *Estheria minuta*, var. *Brodieana*, sometimes appears on the same bed-plane.

8. Candona Kotahensis, sp. nov. Pl. V, fig. 25.

Cypris, *Hislop*. Quart. Journ. Geol. Soc., 1861, vol. xvii, pp. 348 and 353; Journ. Bombay Asiatic Society, 1861, vol. vi, p. 201.

Length, $\frac{1}{30}$ inch. Breadth, about $\frac{1}{60}$ inch.

Carapace sub-cylindrical, smooth; carapace-valves oblong, with equally rounded ends; dorsal margin neatly rounded in front and behind.

This *Candona* is plentiful with *Estheria Kotahensis* in shale at Kotah, on the Pranhita, Central India (see p. 52). It is found also in a limestone there.

The same general resemblances are to be observed for this form as in the case of *C. globosa, C. Rogersii*, &c. As it is advisable that we should be able to recognize it by name, I give it one, though its slight difference of outline is the only tangible feature of distinction.

9. Cypridea Valdensis, *Sowerby*, sp. Pl. V, figs. 26—30.

Cypris Faba, *Sowerby* (not *Desmarest*). Annals Philos., 1824, vol. viii, p. 376; Min. Conch., p. 485.

Cypris Valdensis, *Sowerby*. Trans. Geol. Soc., 2nd ser., 1829, vol. iv, p. 177 and p. 344, pl. 21, fig. 1.

— — *Dunker*. Monogr. Norddeutsch. Wealdenbildung, 1846, p. 59, pl. 13, figs. 24, 29.

Height, about $\frac{1}{32}$ inch. Length, about $\frac{1}{25}$ inch.

Valves of this Cyprid, both with and without the antero-ventral notch, occur

abundantly in the Wealden shales of Hanover (with *Estheria;* see above, p. 104), as we find them in England also, both in the Weald Clay and the Purbeck Beds. The variations in size, shape, and surface-condition, such as are shown in figs. 26—30, with others intermediate, are also met with in England.

M. Bosquet judiciously proposed the term *Cypridea* for these Wealden *Cypridæ* ('Descript. Entom. Tertiair.,' 1850, p. 48); and I have already pointed out ('Monogr. Tert. Entom.,' 1850, p. 9 & p. 21) that they are related to the recent *Cyprideis*, which, though probably a sub-genus of *Cythere*, inhabits fresh and brackish water.

10. Cypridea oblonga (?), *Roemer*, sp. Pl. V, figs. 31—34.

Cypris oblonga, *Rœmer*. Verstein. Nordd. Oolithengeb. Nachtrag, 1839, p. 52, pl. 20, fig. 21.
— — *Dunker*. Monog. Nordd. Wealdenbild., 1846, p. 60, pl. 15, fig. 26.

In company with *C. Valdensis*, this narrower form occurs plentifully in the Wealden shale of Hanover (with *Estheria*); and although in the specimens I have examined I cannot detect the antero-ventral notch, it may still exist in some, as figured by Dr. Dunker. Fig. 33 is most like the form illustrated in the 'Monogr. Nordd. Weald.;' but I think that variation of growth and modification by pressure may have given rise to the somewhat similar valves figs. 31, 32, and 34. These are all freely mixed on some planes of the shale, and seem to offer intermediate gradations, even into *C. Valdensis*, with which they also occur. They are, moreover, generally much crushed, and their margins are not clearly exposed.

Figs. 31 and 34 are not unlike the *Candonæ* noticed in the foregoing pages and figured in Pl. V, but for the present I propose to leave them as here arranged, hoping for a future opportunity of elucidating all the Wealden *Cypridæ*.

INDEX.

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SUPPLEMENTAL NOTES

TO THE

MONOGRAPH OF THE FOSSIL ESTHERIÆ.

I. The recent *Estheriæ, E. Dunkeri, E. Jonesi, E. Loftusi, E. Caldwelli, E. Rubidgei,* and *E. Macgillivrayi,* and *Limnetis Gouldii* (p. 7), have been described and figured by Dr. Baird in the 'Proceedings of the Zoological Society' for 1862, p. 147, &c., pl. 15.

II. With reference to the probability of some fossil *Estheriæ* still passing as *Aviculidæ*, &c. (p. 13), it should be remarked that Prof. M'Coy has already intimated that some fossils regarded as Molluscs may prove to be Entomostraca ('Synopsis of the Carboniferous Fossils of Ireland,' 1842, p. 164).

III. Another locality for *Estheria membranacea* (p. 14) is Banniskirk, Caithness.

IV. To the list of localities for *Estheria minuta* in Germany, enumerated at pages 41, 50, 55, &c., several may be added from C. W. Gümbel's 'Geognostische Beschreibrung des bayerischen Alpengebirges und seines Vorlandes' (8vo, Gotha, 1861), a national geological work of great value. Besides the classification of the Triassic beds of Würtemberg, given at pp. 46—49 of the 'Monograph,' we now have the grouping of the Bavarian Trias, for comparison with that of Alsace (p. 53) and England (pp. 62—65); and this is the more interesting as *Estheria minuta* occurs in two of the divisions of the Trias in the Bavarian Alps, and at least in one (the Bunter) on the south side of the Alps.

Herr Gümbel thus groups the members of the Alpine Trias of Bavaria:

- I. Keuper
  - Upper Keuper or Rhætic Group
    1. Upper Keuper-limestone (Oberer Keuperkalk oder Dachsteinkalk); with *Megalodus triqueter.*
    2. Upper Shell-keuper (Oberer Muschelkeuper); with *Avicula contorta* and the Bone-bed.

    — Kössen and Gervillia Beds.
  - Middle Keuper or Dolomite Group
    1. Plattenkalk; with *Rissoa Alpina.*
    2. Hauptdolomit. Dachstein-Dolomit.
    3. Gyps und Rauhwacke.
  - Lower Keuper or Lettenkohle Group
    1. Lower Shell-keuper (Unterer Muschelkeuper); with *Cardita crenata.* [*Estheria minuta.*] Raibl Beds.
    2. Lower Keuper-limestone (Unterer Keuperkalk); with *Monotis salinaria* and *Ammonites globosi.* [*E. minuta.*] Hallstätt Beds, Esino-limestone, &c.
    3. Lettenkeuper, shales and sandstone; with *Halobia Lommeli* and *Pterophyllum longifolium.* [*E. minuta.*] Partnach and St.-Cassian Beds.

II. Muschelkalk. (*Encrinus liliiformis*, &c.) Guttenstein-limestone, &c.

III. Buntsandstein Formation . . {
1. Haselgebirgschichten; with Gypsum and Rocksalt. [*E. minuta*?]
2. Buntsandstein; with *Myophoria vulgaris* and *Myacites Fassaensis*. [*E. minuta*.]
3. Alpenmelaphyr (Trap-rocks).

The analogous groups of strata in the Tyrol and other parts of the Alps are indicated by Herr Gümbel's tables at pages 116 and 192.

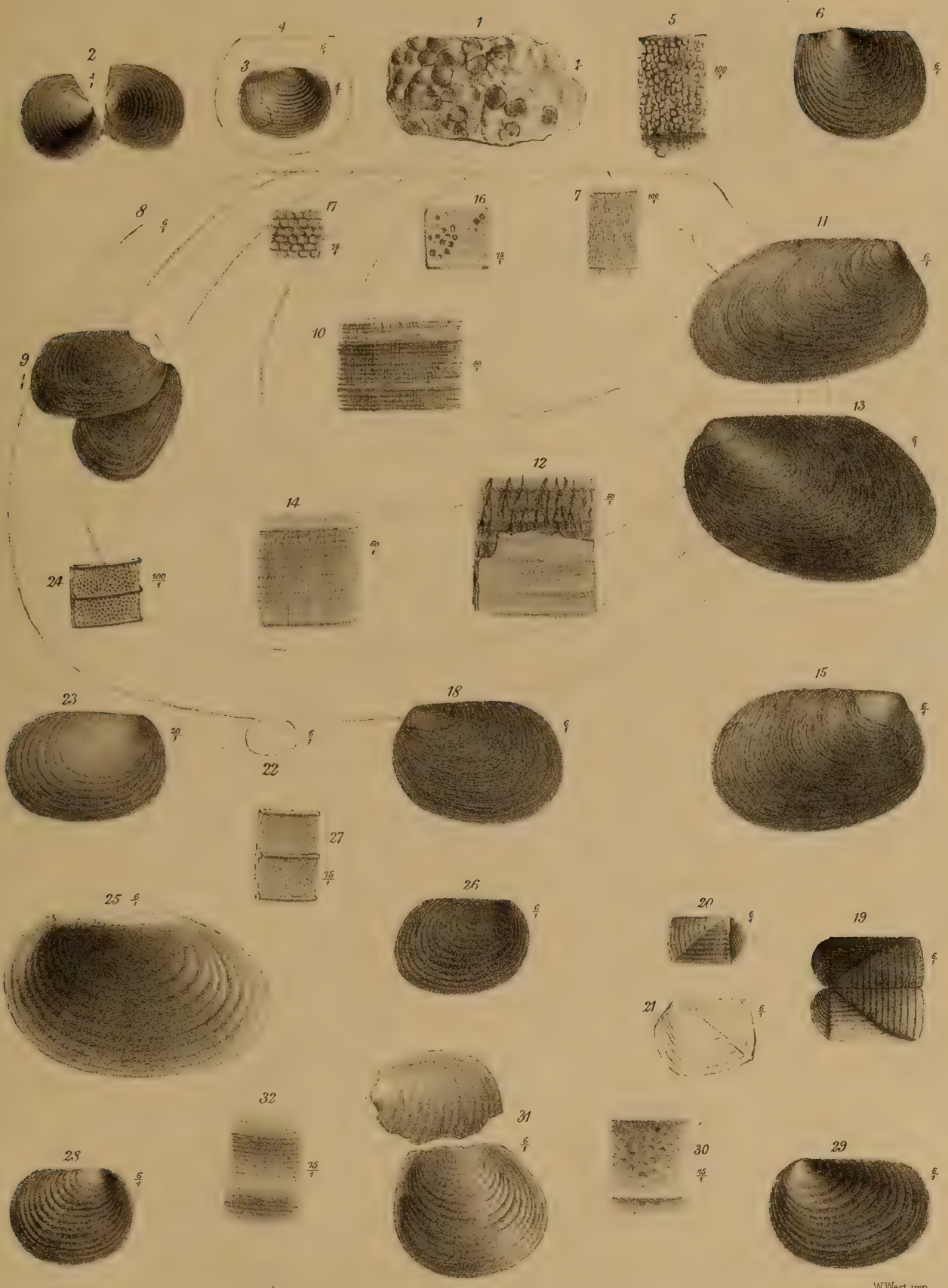
Gümbel states that *Posidonomya minuta* [*Estheria minuta*] occurs in the "Buntsandstein" on both sides of the Alps (pp. 155 and 181); that it occurs in the Lettenkeuper of the Bavarian Alps, at the Partnachthal-Enge (p. 219); in the Lower Keuper-limestone at the Heiterwand, near Imst (p. 225); in the Lower Shell-keuper at the following localities:—"Wettersteinalp bei Garmisch; Hinterriessthal am grossen Falken; Fermesbach unter Schlageck; Hochalpe unter der Alpspitze; Gasfeld am Daumen im Algäu" (p. 273).

V. In treating of the history of the deposits containing *Estheria ovata* (pages 84 *et seq.*), by inadvertence no mention is made of the opinions expressed by M. Jules Marcou as to the age of these beds. In the 'Bulletin de la Soc. Géol. de la France,' 2e sér., vol. vi, 1849, and in his 'Geological Map of the United States' (Boston, 1853), M. Marcou referred the Coal-formation of Richmond, Virginia, to the Lias or the Keuper. In his "Résumé explicatif d'une carte géologique des États-Unis," &c., 1855 ('Bull. Soc. Géol. France,' 2e sér., vol. xii), he referred this coal to the Keuper. In his 'Lettre sur la Jura,' Zurich, December, 1857, after noticing Prof. Emmons's views of the age of the Coal-formation of Eastern Virginia and of North and South Carolina (see 'Monograph,' p. 90), he states that he had himself referred it to the New Red Sandstone series, in 1853, and that Von Buch held the same opinion. In his 'Geology of North America,' 4to, Zurich, 1858, he referred the Red Sandstone of Connecticut, &c., and the Coal-formation of Eastern Virginia, &c., to the Keuper, and, in a note at p. 13, gave a history of his opinions on the subject (with remarks on those of the Profs. Rogers); and here he also quoted O. Heer's remarks on the Triassic relationship of some fossil plants collected by him in Chesterfield County, Virginia, and C. Bunbury's reasons for having been induced, in 1847, to regard the Virginian fossil plants as Liassic (some specimens being imperfect, and the Basle and Baireuth plant-beds being at that time classed with the Lias). In his 'Reply to the Criticisms of J. D. Dana,' 1859, M. Marcou, in mentioning the "New Red in North Carolina and Virginia," again refers to Prof. Heer's letter on the fossil plants, and explains how it passed into 'Silliman's American Journal.' Lastly, in his 'Dyas et Trias,' 1859, he quotes and accepts Prof. Emmons's classification of the strata of the Carolina Coal-formation as Triassic and Permian, and explains at large his opinion that the Permian and Trias ought to be regarded as one great system, belonging rather to the Secondary or Mesozoic than to the Palæozoic period.

PLATE I.

FIG.

1. *Estheria membranacea* (p. 14).—A group on sandy flagstone, nat. size. Caithness.
2. „ „ A pair of valves, open, and somewhat displaced; their dorsal edges approximate; the ridges lost in wrinkles: × 4 diam. Caithness.
3. „ „ A single valve (right): × 4 diam. Caithness.
4. „ „ Outline of the same valve, × 6 diam., for comparison with other *Estheriæ* magnified 6 times. Caithness.
5. „ „ The surface between two ridges, × 100 diam. Probably showing the effects of sand-grains interfering with the natural ornament. Caithness.
6. „ „ Left valve, well preserved, from Kokenhusen, Livonia: × 6 diam.
7. „ „ Ornament of an interspace of the same: × 100 diam.
8. *Estheria striata*, var. *Binneyana* (p. 28).—From near Chesterfield, Derbyshire; outline of valve: × 6 diam.
9. „ „ „ A pair of displaced valves; nat. size. Near Chesterfield.
10. „ „ „ Portion of the surface: × 50 diam. Chesterfield.
11. *Estheria striata*, var. *Beinertiana* (p. 25).—Right valve from Shaly Brow, Lancashire: × 6 diam.
12. „ „ „ Portion of the surface of the same, showing the nearly smooth outside, and the wrinkled interior: × 50 diam.
13. „ „ „ Left valve; from Silesia: × 6 diam.
14. „ „ „ Portion of the surface of the same: × 50 diam.
15. *Estheria striata*, var. *Tateana* (p. 26).—Right valve; Lammerton, Berwickshire: × 6 diam.
16, 17. „ „ Cellular structure, remaining in the shale; Lammerton: × 75 diam.
18. „ „ „ Left valve of a shorter individual; Lammerton: × 6 diam. [A still shorter form is shown in the woodcut at p. 26.]
19. *Leaia Leidyi*, var. *Williamsoniana* (p. 117).—The inside view of two conjoined valves; Ardwick, Manchester: × 6 diam.
20. „ „ „ Right valve, outside; Ardwick: × 6 diam.
21. *Leaia Leidyi*, var. *Salteriana* (p. 119).—Outline of left valve; Fifeshire: × 6 diam.
22. *Estheria exigua* (p. 37).—Right valve. (Probably young.) Kargala, Russia: × 6 diam.
23. „ „ The same valve: × 20 diam.
24. „ „ Portion of the surface: × 100 diam.
25. *Estheria Portlockii* (p. 40).—Hollow mould of right valve; Rhone Hill, Tyrone: × 6 diam.
26. *Estheria tenella* (p. 31).—Right valve; Oschatz, Saxony: × 6 diam.
27. „ „ Portion of the surface of the same: × 75 diam.
28. *Estheria minuta* (p. 42).—Right valve, its ridges lost in wrinkles; Sinsheim: × 6 diam.
29. „ „ Left valve of a larger and better preserved specimen; Sinsheim: × 6 diam.
30. „ „ Portion of the surface of another specimen, showing the reticulated interspace between the ridges: × 75 diam.
31, 32. *Inoceramus* (*Posidonomya*) *Suessii*, Oppel (p. 12).—From the bluish shale of the Lower Oolite (zone of *Ammonites torulosus*), Kandern, Baden; for comparison with *Estheria minuta*. Fig. 31, portion of a valve, and mould of a part of another: × 6 diam. Fig. 32, portion of the surface: × 75 diam. (This shell occurs also in the Oxford Clay near Peterborough.)



George West. lith ad nat. W. West imp.

FOSSIL ESTHERIÆ, &c.

PLATE II.

FIG.

1. *Estheria minuta.*—Left valve, well-preserved; Pendock, Worcestershire: × 6 diam.
2. „ „ Dorsal profile of the same: × 6 diam.
3. „ „ Portion of the surface of the same: × 50 diam.
4. „ „ Right valve; Somerton, Somersetshire: × 6 diam.
5. „ „ Left valve; Shrewley, Warwickshire: × 6 diam.
6. „ „ Dorsal profile of the same: × 6 diam.
7. „ „ Portion of the surface of the same: × 50 diam.
8. „ „ Portion of the surface of a specimen from Frome, Somersetshire, showing a smaller reticulation: × 50 diam.
9. *Estheria minuta*, var. *Brodieana* (p. 66).—Right valve; Linksfield, Elgin: × 6 diam.
10. „ „ „ Portion of the surface of the same: × 50 diam.
11. „ „ „ Portion of the surface of another specimen, from the same place, showing a more linear reticulation: × 50 diam.
12. „ „ „ Right valve; Wainlode, Gloucestershire: × 6 diam.
13. „ „ „ Dorsal profile of the same: × 6 diam.
14. „ „ „ Left valve, from the same place: × 6 diam.
15. „ „ „ Portion of the surface of another specimen, from the same place: × 50 diam.
16. *Estheria Mangaliensis* (p. 78).—Left valve; Mangali, Central India: × 6 diam.
17. „ „ Portion of the surface: × 25 diam.
18. „ „ Portion of an interspace: × 100 diam.
19. „ „ Portion of the surface where the ridges are lost in overlapping laminæ: 100 diam.
20. „ „ Right valve of a subquadrate individual: × 6 diam.
21. „ „ Left valve of a young individual, ovate-oblong: × 6 diam.
22. „ „ Right valve of a young individual, subovate: × 6 diam.
23. „ „ Right valve of a young individual, subquadrate or suborbicular: × 6 diam.
24. *Estheria Kotahensis* (p. 81).—Left valve; Kotah, on the Pranhita, Central India: × 6 diam.
25. „ „ Portion of surface: 100 diam.
26. *Estheria ovata* (p. 84).—Right valve of a youngish individual; Prince Edward, near Richmond, Virginia: × 6 diam.
27. „ „ A pair of valves (somewhat restored); Prince Edward, Richmond: × 6 diam.
28. „ „ Right valve; Harding's pit, near Richmond, Virginia: × 6 diam.
29. „ „ Portion of the surface of the same: × 50 diam.
30. „ „ Portion of the surface of the same: × 100 diam.
31—38. „ Portions of the surface: × 50 diam. Figs. 31, 32, 33, 36, and 38, are from Richmond; figs. 34, 35, and 37 are from Dan River.
39. *Estheria tenella* (p. 31).—Right valve; Lanarkshire: × 6 diam. (For its ornament, see Pl. V, fig. 7.)

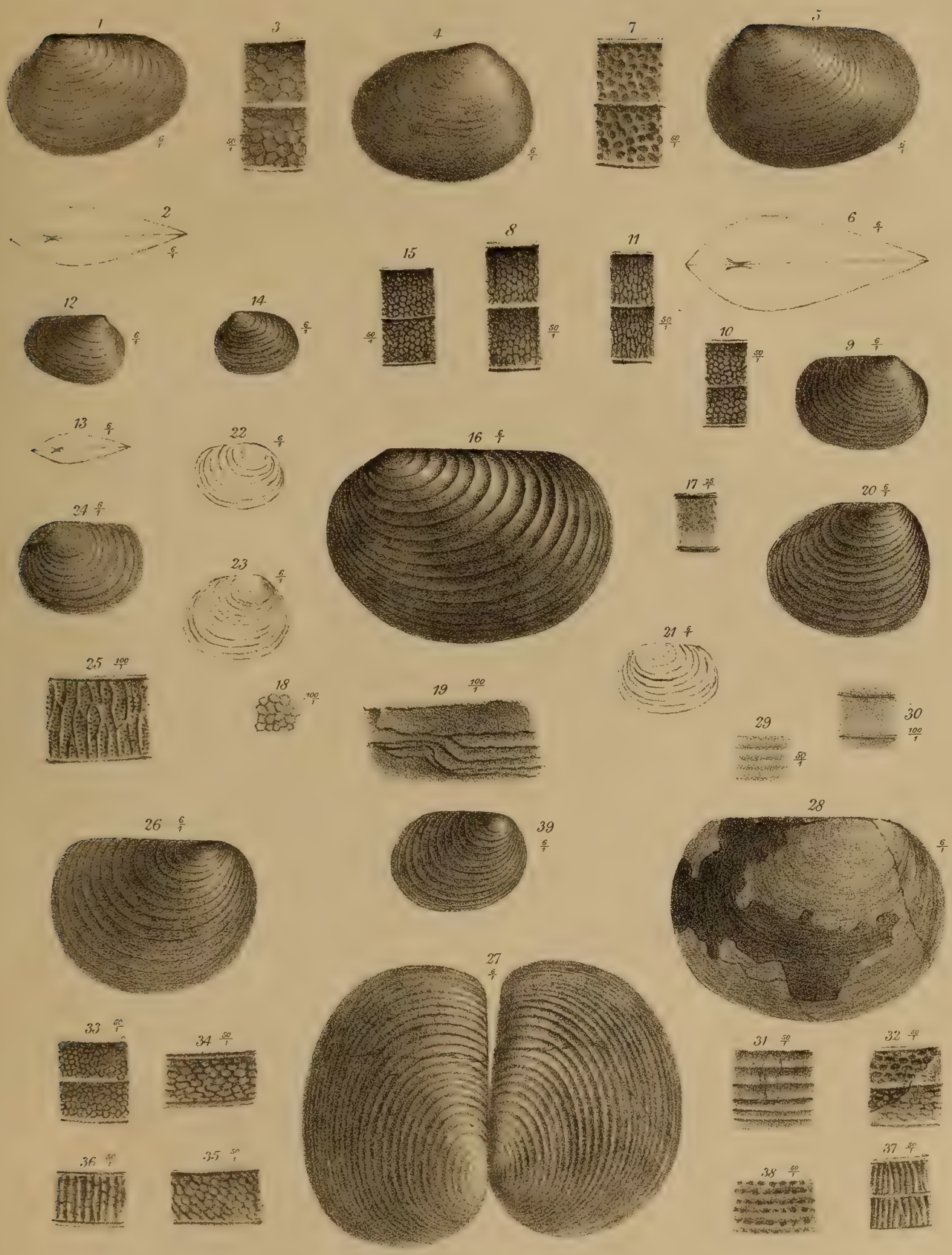


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PLATE III.

Fig.

1. *Estheria Murchisoniæ* (p. 100).—Right valve; Isle of Skye: × 6 diam.

2. „ „ Smaller specimen: × 6 diam.

3—12. „ „ Portions of the surfaces, mostly of different specimens: × 50 diam.

13. *Estheria concentrica* (p. 101).—Left valve; Scarborough: × 6 diam.

14. „ „ Dorsal profile of the same.

15. „ „ Portion of the surface: × 50 diam.

16. „ „ Outline of the right valve of the specimen shown at fig. 13: nat. size.

17. „ „ Outline of a larger specimen: nat. size.

18. *Estheria elliptica*, var. *subquadrata* (p. 109).—Right valve; Bulverhithe, Sussex: × 6 diam.

19. „ „ „ Another specimen (left valve) from Bulverhithe: × 6 diam.

20—22. „ „ „ Portions of the surface of specimens from Bulverhithe: × 50 diam.

23. „ „ „ Right valve; Tunbridge Wells: × 6 diam.

24. „ „ „ Portion of the surface: × 50 diam.

25—27. „ „ „ Right valves; East Cliff, Hastings: × 6 diam.

28, 29. „ „ „ Portions of the surfaces of the same: × 50 diam.

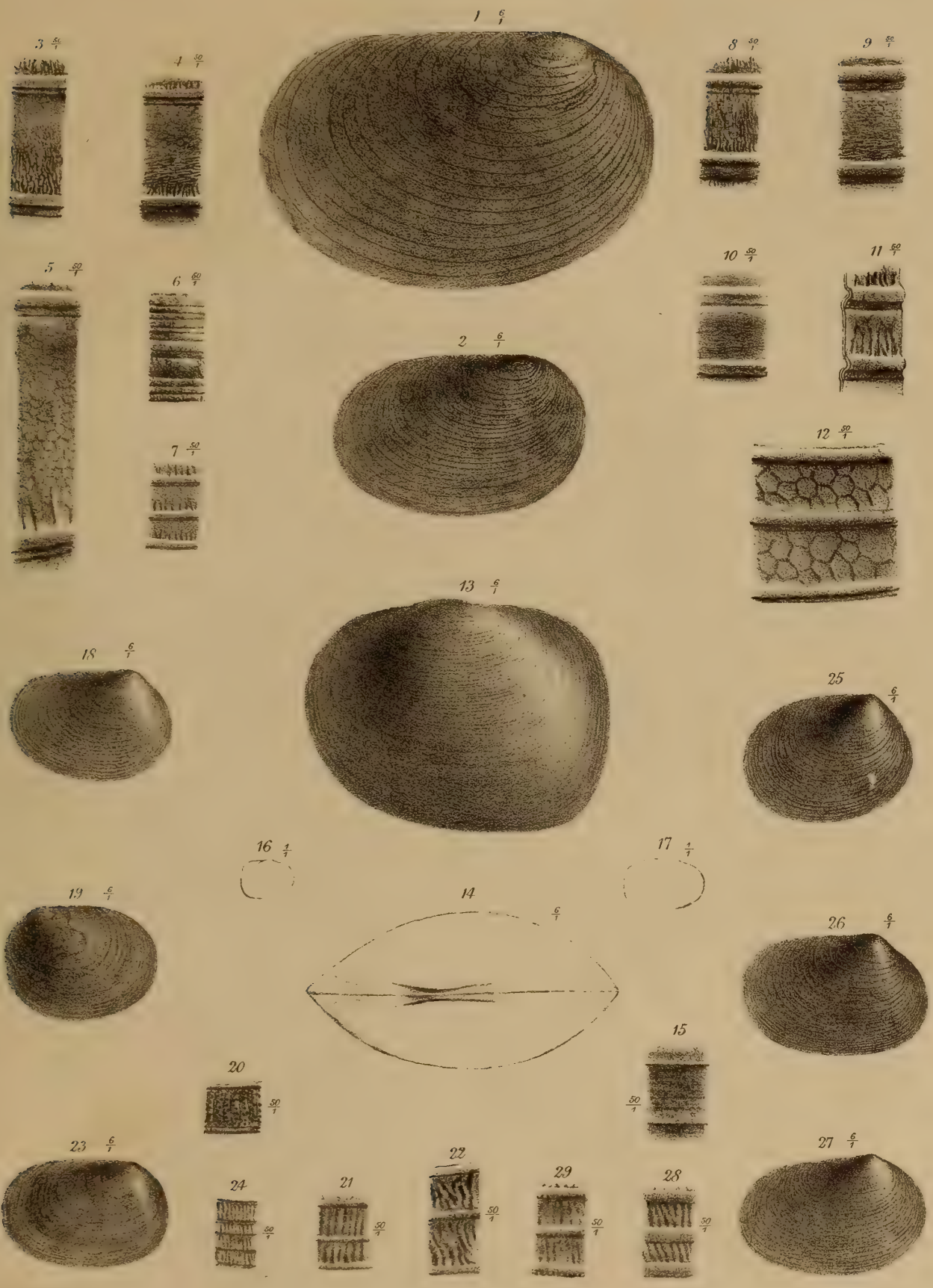

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PLATE IV.

Fig.

1. *Estheria elliptica* (p. 103). Right valve; Obernkirchn, Hanover: × 6 diam.
2. „ „ Right valve of a smaller individual, subquadrate or ovate-oblong: × 6 diam.
3. „ „ Right valve of a suborbicular individual: × 6 diam.
4, 5. „ „ Portions of the surface of fig. 1: × 50 diam.
6. „ „ Left valve of small individual, ovate-oblong or subquadrate, with distinct ridges: × 6 diam.
7. „ „ Portion of the surface of the same, taken from near the ventral edge: × 100 diam.
8. *Estheria Forbesii* (p. 109).—Right valve; Cacheuta, South America: × 6 diam.
9. „ „ [Within the outline of *E. Middendorfii*.] A smaller suborbicular specimen: × 6 diam.
10. „ „ A still smaller individual: × 6 diam.
11. „ „ Portion of the surface of fig. 8: × 50 diam.
12. *Estheria Middendorfii* (p. 111).—Outline of the left valve; Tourga, Siberia: nat. size.
13. „ „ Outline of the same: × 6 diam.
14. „ „ Natural cast, in shale, a portion of the surface: × 50 diam.
15. „ „ The surface-ornament restored from the cast, fig. 14: × 50 diam.
16. „ „ Portion of the surface, including parts of two interspaces, one of which is partly occupied by the real carapace, the other being almost all a cast or impression in shale; the globular bodies and casts are referable to ova: × 50 diam.
17, 18. „ „ Natural casts or impressions of portions of the carapace; fig. 17 corresponding to such a portion as the lower part of fig. 16: × 50 diam.
19. „ „ Portion of the reticulated surface: × 80 diam.
20—22. „ Some of the oviform bodies: × 80 diam.

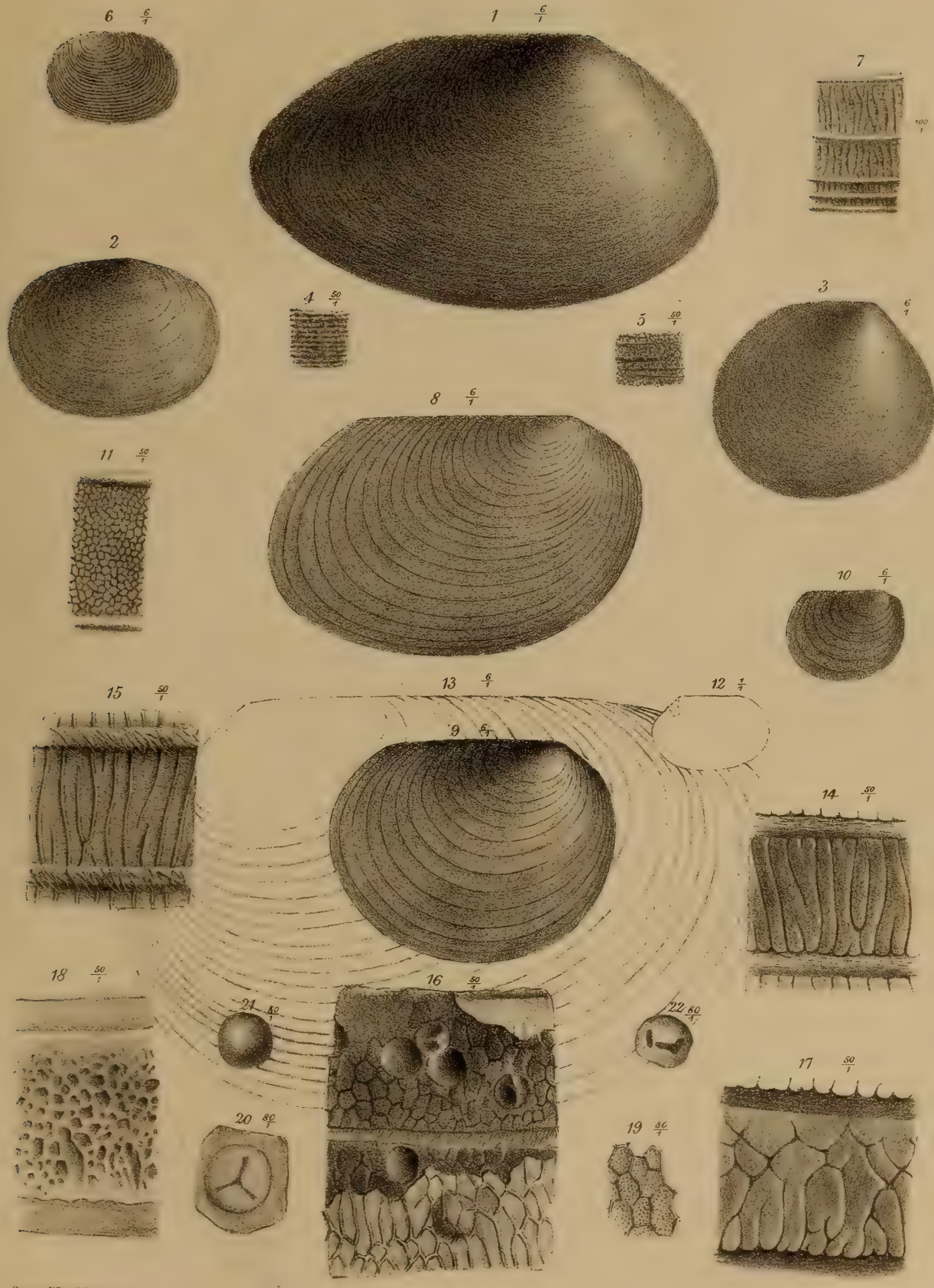

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PLATE V.

Fig.

1. *Estheria tenella* (p. 31).—Left valve, small specimen; Bradford Coal-pit, near Manchester: × 6 diam.
2, 3. „ „ Other larger specimens (left and right valves): × 6 diam.
4. „ „ Portion of the surface of one of these: × 75 diam.
5. „ „ Left valve; Astley, Lancashire: × 6 diam.
6. „ „ Right valve; Murgthal, Schwarzwald: × 6 diam.
7. „ „ Portion of the surface; Lanarkshire: × 100 diam. [See Pl. V, fig. 7, for the valve, × 6 diam.]
8. *Estheria minuta* (p. 42).—Right valve; Sinsheim, Baden: × 6 diam. [For comparison with Pl. I, figs. 28 and 29.]
9. „ „ (p. 53.)—Left valve; Sulzbad, Bas-Rhin: × 6 diam.
10. *Estheria minuta*, var. *Brodieana* (p. 66).—Portion of the surface, showing linear reticulation; Linksfield: × 50 diam. [Compare Pl. II, figs. 9—11.]
11. *Leaia Leidyi* (p. 116).—Outline of the two valves, open, in juxtaposition; Pottsville, Pennsylvania: nat. size. [After Lea.]
12. „ „ The same: × 5 diam. [After Lea.]
13, 14. *Candona* (?) *Salteriana* (p. 122)—Bradford Coal-pit, near Manchester: × 30 diam.
15. *Candona* (?) *Tateana* (p. 123).—Lammerton, Berwickshire: × 30 diam.
16. *Beyrichia subarcuata* (p. 120).—Astley, Lancashire: × 30 diam.
17. „ „ Portion of the surface: × 75 diam.
18. *Beyrichia Pyrrhæ* (p. 121).—Burakova, Russia: × 30 diam.
19. „ „ Portion of the surface: × 75 diam.
20, 21. *Candona Rogersii* (p. 124).—Richmond, Virginia; and Deep River, North Carolina: × 30 diam. [For the punctated *Candona Emmonsii*, see woodcut, fig. 12, p. 126.]
22. „ „ Cast, in shale; Culpepper County, Virginia: × 30 diam.
23, 24. *Candona globosa* (p. 126).—Linksfield, Elgin. Two left-hand valves, showing muscle-spot: × 30 diam.
25. *Candona Kotahensis* (p. 127).—Left valve; Kotah, on the Pranhita, Central India: × 30 diam.
26—28. *Cypridea Valdensis* (p. 127).—One right and two left valves, of somewhat variable outline; Obernkirchn, Hanover: × 30 diam.
29. „ „ Portion of the surface of one of these valves: × 75 diam.
30. *Cypridea Valdensis* (?).—Probably a young individual; Obernkirchn: × 30 diam.
31—34. *Cypridea oblonga* (?) (p. 128). Probably varieties or modified valves (fig. 33 is most like the type); Obernkirchn, Hanover: × 30 diam.

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FOSSIL ESTHERIÆ, CYPRIDÆ, &c.